STUDIES ON THE ENCHYTRAEIDAE OF NORTH AMERICA

BY

PAUL SMITH WELCH
A.B., James Millikin University, 1910
A.M., University of Illinois, 1911

THESIS

Submitted in Partial Fulfilment of the Requirements for the

Degree of

DOCTOR OF PHILOSOPHY

IN ZOOLOGY

IN

THE GRADUATE SCHOOL

OF THE

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Bulletin of the Illinois State Laboratory of Natural History.
Vol. X, Art. III.

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ARTICLE III.—*Studies on the Enchytræidæ of North America.**

BY PAUL S. WELCH, PH.D.

INTRODUCTION

In spite of the fact that the forms belonging to the family *Enchytræidæ* are common in many parts of North America, it is a group of which little is known. Less than a dozen references constitute the literature on the North American species. The writer has been carrying on investigations in this field in Illinois for the last three years, and the following paper represents some of the results of this study. He wishes to express his indebtedness to Professor Frank Smith, under whose direction this work has been done. Acknowledgments are also due as follows: to the Director of the Sewage Testing Station at Chicago, for permission to work in the laboratories of that institution; to Dr. Arthur Lederer, chief chemist of the Testing Station, and to his associates, for the many courtesies extended to the writer during his work at that place; and to Professor S. A. Forbes, for material from the collections of the Illinois State Laboratory of Natural History.

The *Enchytræidæ,* as known at present, include sixteen genera and a large number of species. The family is wide-spread in its distribution, being common in various parts of the American continent, generally distributed in Europe, and reported from Siberia, New Zealand, and North Africa. It appears, however, to be largely confined to the cold and temperate regions of the world. Specimens of the family have been met with upon the ice of the glaciers; and twenty-seven species have been recorded for Alaska. The warm sections of the globe apparently have a very limited enchytræid fauna, since only a small number of species have been reported from them. Enchytræids are found in various kinds of situations. Many are terrestrial, some are aquatic, and others are reported as being amphibious. Although the majority of the aquatic forms are fresh water species, several species are found in marine situations. *Enchytræidæ* are quite similar to the earthworms in some respects, having (1) the simple setæ, (2) the wide separation of the spermathecæ from the spermiducal pores, (3) paired or unpaired glands comparable to the calciferous glands of earthworms, and (4) the thick body wall. In other respects they

*Contributions from the Zoological Laboratory of the University of Illinois, under the direction of Henry B. Ward, No. 26.

resemble the lower *Oligochæta,* viz., in (1) the presence of numerous lymphocytes in the cœlomic fluid; in (2) the limitation of the sperm ducts to two consecutive somites, one of which contains the internal opening and the other the external opening; and (3) in the reduction of the oviduct to a mere pore.

Michaelsen ('00, p. 66) defines the family as follows: "Borsten stiftförmig oder einfach hackenförmig, ohne deutlichen Nodulus, gerade oder schwach S-förmig gebogen, einfach-spitzig, meist zu mehreren (3–12) in fächerförmigen Bündeln, selten zu 2, einzeln oder ganz fehlend. Kopfporus vorhanden. Nephridialporen vor den ventralen Borstenbündeln. Gürtel am 12. Segm. und über mehr oder weniger grosse Teile der benachbarten Segm. Männliche Poren 1 Paar, am 12. Segm., vor den ventralen Borstenbündeln; weibliche Poren 1 Paar, am 13. Segm., vor den ventralen Borstenbündeln; Samentaschenporen meist 1 Paar, auf Intsegmtf. 4/5, selten 2 Paar auf Intsegmtf. 3/4 und 4/5. Darm mit dorsalem Schlundkopf, durch den mehrere Paare Septaldrüsen, vor dem Dissep. 4/5 und einigen folgenden gelegen, ausmünden. Blutgefässsytem einfach; Rückengefäss nur im Vorderkörper, mit dem Bauchgefäss durch wenige, meist 3, Transversalgefässpaare verbunden. Meganephridisch; Nephridien mit massigem Postseptale. Hoden an Dissep. 10/11; Samentrichter mit dicker, drüsiger Wandung und engem Lumen; walzen oder tonnenförmig, selten schief trichterförmig, vor Dissep. 11/12. Ovarien an Dissep. 11/12; Eitrichter rudimentär, an Dissep. 12/13; Eier gross, dotterreich, einzeln oder zu mehreren in Cocons abgelegt. In einzelnen Fällen sämtliche Geschlechtsorgane mit Ausnahme der Samentaschen um 3 oder 4 Segm. nach vorn verschoben."

The *Enchytræidæ* are fast coming to be one of the larger families of *Oligochæta.* The sixteen genera* of the family are as follows: *Mesenchytræus* Eisen, *Enchytræus* Henle, *Michaelsena* Ude, *Lumbricillus* Oersted, *Marionina* Michaelsen, *Buchholzia* Michaelsen, *Stercutus* Michaelsen, *Bryodrilus* Ude, *Henlea* Michaelsen, *Fridericia* Michaelsen, *Distichopus* Leidy, *Achæta* Vejdovský, *Propappus* Michaelsen, *Euenchytræus* Bretscher, *Hepatogaster* Čejka, and *Hydrenchytræus* Bretscher.

The genus *Chirodrilus* Verrill has been the subject of some dispute. Both Vejdovský and Vaillant classed it with the *Tubificidæ,* while

*Since this paper was written and presented for publication three new genera have been described from the Old World, namely, *Grania* Southern, *Litorea* Cejka, and *Chamædrilus* Friend. A number of new foreign species have also been described, so that the numbers of species now assigned to *Henlea, Lumbricillus, Fridericia,* and *Enchytræus* slightly exceed those given in the body of this paper.

Beddard ('95, p. 314) and Michaelsen ('00, p. 88) classed it among the *Enchytræidæ*. Later, Michaelsen ('03b, p. 50) included it with the *Tubificidæ*. As there seems to be good ground for putting it with the *Tubificidæ* it has been omitted from the above list.

The abundance of enchytræid life in North America is indicated by the fact that in spite of the small amount of investigation which has been made in this group, nine of the above-listed genera are known to have representatives on this continent, and it seems safe to predict that future investigation will reveal still other genera. An indication of what further studies may yield is afforded by the work of Eisen on the Pacific coast, where random collecting gave material from which he described forty-eight new species distributed among eight genera; and in his introduction he states that he had at the time of writing some fifty or more additional new species from the same region, the description of which was temporarily prevented by unavoidable circumstances.

Of the above-listed genera only *Distichopus*, which was described by Leidy in 1882 from the eastern United States, is, so far as our knowledge goes, limited to North America. The following genera are represented in this country: *Mesenchytræus, Enchytræus, Michaelsena, Lumbricillus, Marionina, Bryodrilus, Henlea, Fridericia,* and *Distichopus.*

Key to the Genera of North American Enchytræidæ

1 (2) Setæ not disposed in bundles; occur singly when present; usually absent from many of the somites.......... *Michaelsena*
2 (1) Setæ disposed in bundles.
3 (4) Setæ disposed in two bundles on each somite..... *Distichopus*
4 (3) Setæ disposed in four bundles on each somite.
5 (6) Dorsal pores present............................ *Fridericia*
6 (5) Dorsal pores absent.
7 (8) Œsophagus merges suddenly into the intestine........ *Henlea*
8 (7) Œsophagus merges gradually into the intestine.
9 (10) Setæ straight and of equal length................ *Enchytræus*
10 (9) Setæ sigmoid.
11 (12) Testes plurilobed .... *Lumbricillus*
12 (11) Testes undivided.
13 (14) Origin of dorsal vessel intraclitellar; blind diverticula in connection with alimentary tract somewhere in VI–VIII...... .... *Bryodrilus*
14 (13) Origin of dorsal vessel postclitellar; no diverticula in connection with anterior part of alimentary canal.

15 (16) Nephridia with a wide, closely wound canal and slight intermediate substance .... *Mesenchytræus*
16 (15) Nephridia with narrow, loosely wound canal and well-developed intermediate substance .... *Marionina*

HENLEA Michaelsen

The genus *Henlea* was established by Michaelsen in 1889, and although it includes a somewhat heterogeneous assemblage of species, there does not seem to be at present sufficient grounds for breaking up the genus into different generic types. It is distinguished from the other genera by the following characters: (1) the sudden change in the diameter of the digestive tract where the œsophagus passes into the intestine; and (2) the anteclitellar origin of the dorsal vessel. As a rule there are diverticula at the beginning of the intestine. The nearest relative of *Henlea* is *Bryodrilus,* although *Buchholzia* also stands close. Michaelsen ('03b, p. 51), in discussing the phylogeny of the *Enchytræidæ,* placed *Henlea* at the base of the system, as the most primitive genus, on the ground that the forms belonging to this group show the greatest diversity in the character of the setæ. Later the same writer ('05c, p. 24) described a new genus, *Propappus,* which is in a number of respects more primitive than *Henlea,* and must be regarded as the oldest of the known enchytræid genera. One of the striking characters of *Propappus* is the presence of forked setæ.

Forty-two species and two varieties are assigned to *Henlea* at the present time. Of this number seven are doubtful, either as regards their being valid species, or on account of their generic assignment. The following seem worthy of mention. *H. lefroyi,* described by Beddard ('05, p. 62) from India and placed provisionally in this genus, is said to have a dorsal vessel of intraclitellar origin, the intestinal diverticula lacking, and the œsophagus transforming gradually into the intestine. Beddard found it possible to eliminate, by other characters, all of the genera except *Bryodrilus* and *Henlea.* He places the species in *Henlea* because the characteristic intestinal diverticula are sometimes absent—a reason which is open to question. *H. scharffi,* described by Southern ('10a, p. 18) from the White Mountains and placed provisionally in this genus, is described as lacking intestinal diverticula, and the œsophagus as passing gradually into the intestine. The anteclitellar origin of the dorsal vessel seems to be the only good ground for placing the species in this genus.

Taking the genus as a whole, there is a remarkable variation in the different organs. *H. puteana* Vejdovský is unique in having two pairs of spermathecæ. The species of the genus can be grouped in

one of several ways according to the criteria of classification, which may be the character of the setæ, the presence or absence of intestinal diverticula, the presence or absence of peptonephridia, the place of origin of the dorsal vessel, or the presence or absence of ampullæ on the spermathecæ.

Of the assemblage of species included in *Henlea,* four species and two varieties have been described from North America. They are as follows, the type locality for each being given: *H. californica* Eisen (Santa Rosa, Sonoma Co., California), *H. californica,* var. *monticola* Eisen (West Fork, Feather River, California), *H. californica,* var. *helenæ* Eisen (St. Helena, Napa Co., California), *H. ehrhorni* Eisen (Mountain View, San Mateo Co., California), *H. guatemalæ* Eisen (Guatemala City, Central America), and *H. scharffi* Southern (White Mountains, New Hampshire). Two new species, *H. moderata* and *H. urbanensis,* are described in the following pages.

Leidy (Journ. Acad. Nat. Sci. Phil., ser. 2, Vol. 2, 1850, p. 48) described a species under the name of *Enchytræus socialis* from eastern Pennsylvania. The description is so inadequate that it is very uncertain what the species is. Michaelsen ('00, p. 69) regards it as a synonym of *Henlea ventriculosa* Udek., and there appears to be evidence in favor of this view. It thus appears that *H. ventriculosa* may be added tentatively to the list of North American species of this genus.

Michaelsen ('00, p. 67) defines the genus as follows: "Borsten gerade oder schwach S-förmig gebogen. Kopfporus klein, zwischen Kopflappen und 1. Segm.; Rückenporen fehlen. Lymphkörper von einerlei Gestalt, gross, meist discusförmig, selten elliptisch, dunkel granuliert. Der Oesophagus geht im 7., 8. oder 9. Segm. plötzlich in den weiten Mitteldarm über. Ursprung des Rückengefässes anteclitellial, im 8. oder 9. Segm.; Blut farblos; Herzkörper fehlt. Nephridien mit kleinem, einfachem Anteseptale. Hoden massig. Samentaschen einfach, ohne Divertikel, mit dem Oesophagus kommunizierend."

Key to the Species of Henlea known to occur in North America

1 (2)	Spermathecæ with diverticula	*ehrhorni*
2 (1)	Spermathecæ without diverticula.	
3 (4)	No intestinal diverticula present....................	*scharffi*
4 (3)	Intestinal diverticula present.	
5 (14)	Two intestinal diverticula present.	

6 (13) Spermatheca with ampulla having a diameter little or no greater than duct; anteseptal part of nephridium small.

7 (12) Dorsal vessel arises in VIII; peptonephridia connected with digestive tract in IV.

8 (11) Two accessory glands at ectal opening of spermathecal duct; spermathecæ slightly bent.

9 (10) Brain wider than long, concave anteriorly and posteriorly; spermathecæ with lumen approximately straight. . *californica*

10 (9) Brain almost square with only posterior margin concave; spermatheca with an expansion in lumen for storage of spermatozoa which is connected with lumen of intestine by a long narrow contorted canal. . . . . . *californica*, var. *helenæ*

11 (8) Four or more accessory glands at ectal opening of spermathecal duct; spermathecæ sharply bent. . . *californica*, var. *monticola*

12 (7) Dorsal vessel arises in IX; peptonephridia connected with digestive tract in V. . . . . *urbanensis*

13 (6) Spermatheca with well-developed oval ampulla; anteseptal part of nephridium approximately as large as postseptal part. . . . . *guatemalæ*

14 (5) One intestinal diverticulum, which in VIII completely surrounds the digestive tract. . . . . *moderata*

Henlea moderata n. sp.

(Plate VIII, Figs. 1–12)

Definition.—Length, 13–19 mm., average about 16 mm. Diameter, 0.48 mm. Somites, 46–58. Color, whitish yellow. Prostomium somewhat tapering. Head pore at 0/I. Dorsal pores absent. Setæ of unequal length, inner ones slightly shorter; slightly bent; variable in size, inner ones finer; 3–6 per bundle in anterior part of body, 2–4 in posterior part. Clitellum on ½XI–XIII. Lymphocytes elliptical. Brain about one half longer than wide; anterior margin concave; posterior one deeply emarginate; lateral margins convergent cephalad. Peptonephridia present and well developed, connected with digestive tract in V; dorsal and ventral strands in close contact with alimentary canal; ventral strand in VI and VII gives rise to a number of tubules which project into cœlom. Four "taste organs" in buccal cavity, each one provided with a muscular strand which extends to the body wall. Œsophagus passes abruptly into intestine in VIII. Intestinal diverticulum present in VIII, entirely surrounding digestive tract; composed of numerous tubules which ultimately unite into about twelve main tubules, by means of which connection with digestive tract is effected. Dorsal vessel arises in IX. Each nephridium with small anteseptal part; postseptal part about two and one half

times larger, the efferent duct arising from its anterior part. Spermiducal funnel small; length about twice the diameter. Spermathecæ with oval expanded ampulla near ectal end; diminishing in diameter toward ental end; rosette of four glands at ectal opening; spermathecæ unite dorsad of digestive tract to form a short oval tube through which they communicate with lumen of alimentary canal in the posterior part of V.

The characters of the penial bulb are discussed on a later page.

Described from 11 sexually mature specimens. Type and paratypes in the collection of the writer. Paratypes also in the collection of Professor Frank Smith.

The specimens which are the basis of this description were found in late March, 1911, near Urbana, Illinois, in rich soil, under decaying leaves in undisturbed forest land. All of the specimens are sexually mature, showing spermatozoa in the spermathecæ, well-developed egg masses in the body cavity, and developing spermatozoa in XI.

Affinities.—It is somewhat difficult to determine the systematic relations of this species owing to the fact that some of the species which are included in the genus are quite incompletely described. Species which, so far as described, seem to be closely related, might, if more thoroughly worked out, reveal characters which would separate them widely. However, until these meager descriptions are supplemented by further study, one must be content to place each new species in what seems to be its natural position. If the minimum number of distinct differences be considered, this species seems to approach about equally *H. gemmata* Eisen, *H. ochracea* Eisen, and *H. dorsalis* Bretscher, but as these are imperfectly described, the assumption of this relationship must be tentative. *H. gemmata* Eisen differs from *H. moderata* in the characters of the setæ, the spermiducal funnel, the nephridia, the brain, and the spermathecæ; *H. ochracea* Eisen differs in the characters of brain, nephridia, and spermathecæ; and *H. dorsalis* Bretscher shows differences in length and in the character of the brain.

EXTERNAL CHARACTERS

The body is slender and has an average length of about 16 mm., the extremes being 13 and 19. In transverse section it is circular. The diameter is greatest in the region of the clitellum, where it averages about 0.48 mm.; posterior to the clitellum the diameter diminishes only to a very slight degree. In living specimens the body is opaque and whitish yellow. The prostomium (Pl. VIII, Fig. 6) shows a slight but gradual tapering. The intersegmental grooves are quite

distinct in the first three to five somites, but elsewhere are obscure. The number of somites is variable, the average being about 54, the extremes, 46 and 58. The head pore is small and located on 0/I. The clitellum is on ½ XI–XIII and is usually only moderately developed. In the anterior region there are 3–6 setæ per bundle, and in the posterior region 2–4, usually 2 in the last four or five somites. The arrangement of the setæ in the bundle (Pl. VIII, Fig. 3) resembles that in *Fridericia*. The outer setæ of the bundle are longer and heavier than the inner ones, but it should be noted that this difference is less than that usually found in *Fridericia*. In each bundle the proximal ends of the setæ are in rather close proximity to each other and are arranged in transverse linear sequence. Outside of the body wall they spread out fanwise. Close examination shows that, as in *Fridericia*, the setæ are not arranged in pairs, but represent a series of different sizes. The proximal ends are distinctly bent (Pl. VIII, Fig. 9).

INTERNAL CHARACTERS

Lymphocytes.—The lymphocytes (Pl. VIII, Fig. 5) are large and abundant. Their distribution in the cœlom is not uniform; certain regions are well supplied, while other regions are almost destitute. They begin to appear near IV. The space intervening between the septal glands and the reproductive organs is almost completely filled with them except in the region of the intestinal diverticulum, where they are greatly reduced in numbers. Few if any are present in the somites containing the reproductive organs, but beyond them the lymphocytes are always present although not in such numbers as in the anterior parts of the body. They are disc-like or broadly elliptical. The granular cytoplasm contains a conspicuous nucleus. Measurements average as follows: length, 0.085 mm.; width, 0.045 mm.

Brain.—The brain (Pl. VIII, Fig. 1) is in I, II, and III, chiefly in II. It is somewhat heart-shaped. The posterior margin is deeply emarginate and the anterior margin is decidedly concave. The lateral margins converge rapidly cephalad and approach each other closest at a point just posterior to the origin of the commissural nerve trunks. The posterior part of the brain is approximately 2.7 times wider than the anterior part. The dimensions are practically uniform, the ratio of the greatest width to the greatest length being 6:9. The actual measurements are 0.108 mm. for the greatest width, and 0.162 mm. for the greatest length. In transverse section the organ is elliptical in outline. It is attached to the body wall by two pairs of supporting strands which arise from its latero-posterior and posterior parts. The anterior part gives rise to the usual nerve trunks, which extend for-

ward, diverging only slightly up to the point where they begin to pass around the digestive tract. Near this point these trunks divide, giving rise to a pair of branches which continue on into the prostomium. The main pair of trunks extend around the digestive tract, forming the circumœsophageal commissures, uniting again on the ventral side to form the subœsophageal ganglion, which lies partly in I and partly in II.

Peptonephridia.—Two peptonephridia are present, one arising from the dorsal and the other from the ventral side of the digestive tract in the anterior part of V. Both extend caudad and adhere closely to the alimentary canal, and for a considerable part of their extent lie between the epithelial layer and the muscular coat of the latter. Each is composed of two strands which give off at intervals a number of tubules that project freely into the cœlom. In VI both the dorsal and ventral peptonephridia become greatly thickened and enlarged. Near this enlargement the ventral peptonephridium gives rise to a number of tubules which extend around the digestive tract on either side. The terminus of each tubule is in the immediate vicinity of the dorsal vessel. They come into close proximity to the dorsal strands but so far as observed do not unite with them. After giving off these tubules the strands become reduced to their former size and so remain as far as VII, where the ventral peptonephridium becomes thickened again and gives rise to tubules which project freely into the body cavity. These tubules resemble those in VI in general structure but differ in being shorter and fewer in number. They extend dorsad on each side of the digestive tract, but do not reach the dorsal surface. Both peptonephridia end immediately anterior to the intestinal diverticulum, in the posterior part of VII.

Taste Organs ("Geschmacksläppchen").—This species is somewhat unique in having four of these organs (Pl. VIII, Fig. 8) instead of the usual number, two. They extend from the floor of the buccal cavity, and are products of the lining epithelium and structurally like it. These tongue-like organs are sometimes directed caudad, sometimes cephalad, the direction depending on the state of retraction of the pharynx. Four muscle strands, two on either side of the median line, are attached to the wall of the buccal cavity at the bases of these organs and extend obliquely ventro-caudad to the body wall. Vejdovský ('84, p. 99) describes ganglion cells in the bases of the "Geschmacksläppchen" which he studied, but they have not been seen in this species.

Intestinal Diverticulum.—At the junction of the intestine with the œsophagus, in VIII, there arises a structure which is reflected cephalad

over the latter, investing it closely for the greater part of the length of the somite. In cleared mounts it appears as a brownish, almost opaque, mass filling the greater part of the cœlom at the above-mentioned point. It is a single organ with two shallow longitudinal depressions, one dorsal, and the other ventral, the former being the more distinct. Sections (Pl. VIII, Figs. 10 and 11) show the organ to be made up of a series of branching, rather thick-walled tubules, about twelve in number, which extend radially and cephalad. The region of the digestive tract (Pl. VIII, Fig. 10) from which these tubules arise is ciliated, and the basal parts of the lumina of the latter are also ciliated. These tubules give off branches as they extend anteriorly, until the whole mass of the anterior part of the organ is composed of the finer tubules, which lie in very close proximity to each other. The walls of these tubules are distinctly nucleated and appear to be composed of glandular tissue. The whole diverticulum is invested in a peritoneal layer, beneath which is a very much reduced muscle layer—a continuation of the muscle layer of the digestive tract. The perivisceral blood sinus appears at the point of origin of the tubules from the digestive tract. This sinus is continued cephalad, and the reduced spaces which appear between the tubules of the diverticulum are continuations of this sinus. In all of the specimens studied the structure of this organ is uniform in all respects.

The presence of the mid-dorsal and mid-ventral longitudinal grooves suggests the possibility that this organ may have developed from two lateral outgrowths from the digestive tract which came together, fusing at the points of contact; but an examination of the point of origin of the diverticulum shows no evidence that it arose as two separate parts.

Dorsal Blood-vessel.—The dorsal blood-vessel arises from the perivisceral blood sinus in IX. In some of the specimens it shows a conspicuous expansion in IX, immediately after it originates from the sinus; but this is not a constant feature, since some specimens do not show it at all, while others show only a moderate expansion.

Nephridia.—The first nephridia are related to V/VI. There is some variation in their size and shape in the various specimens and in the different regions of the body, although this variation is within rather narrow limits. The anteseptal part (Pl. VIII, Fig. 2) is reduced in size, the postseptal part being about two and one-half times larger. The efferent duct arises near the septum and is longer than the postseptal part.

Spermiducal Funnel.—The small spermiducal funnel (Pl. VIII, Fig. 4) is situated in the posterior part of XI, with its base in close

proximity to the lower part of XI/XII and with its long axis almost parallel to the long axis of the body. The whole organ lies close to the ventral body wall. It varies in shape within narrow limits, but in general it resembles an elongated barrel. It also varies somewhat in dimensions, but the length averages about twice the diameter. The anterior end has a well-differentiated collar which is set off from the body of the organ by a constriction. This collar varies in the degree of the reflection of the margin, which is sometimes about 180° and sometimes only about 45°. The anterior opening is in close proximity to the extremity of the testis. The sperm duct passes through XI/XII very near to its union with the body wall. It is long, much coiled, and confined to XII.

Penial Bulb.—This organ (Pl. VIII, Fig. 12) conforms to the lumbricillid type of penial bulb as defined by Eisen ('05, p. 8), and does not differ markedly in structure from that of the other American species of this genus. It is small, and is not nearly so conspicuous in transverse section as is usual in other *Enchytræidæ*. It is covered by a definite musculature, a continuation of the circular muscle layer of the body wall, which does not at any point penetrate into the body of the bulb. The bulb is composed of two kinds of cells, namely, those surrounding and opening into the penial lumen, and those which fill the peripheral parts of the bulb, some of which appear to open to the surface below the penial pore. The former are elongated, nucleated, and stain very lightly, and are arranged radially around the penial lumen. The peripheral cells are irregularly spindle-shaped and tend to take the stain heavily. The sperm duct penetrates the bulb near the ectal side and joins the penial lumen well within the body of the bulb. When the penial bulb is retracted the penial lumen curves strongly towards the penial invagination, and the penial pore is located well towards the base of the latter.

Ovaries.—These organs occur as usual in XII, attached to the ventral part of XI/XII. They are massive, filling a considerable part of the cœlom in XII. The terminal part of each, which bears the developing egg masses, is usually pushed up into the body cavity until it lies dorsad to the digestive tract.

Spermathecæ.—A single pair of these organs lies in V. The ectal opening of each is laterad in the intersegmental groove IV/V and is surrounded by a number of glands (Pl. VIII, Fig. 7) which form a sort of rosette. There is no marked differentiation of duct and ampulla. Within the ectal region, which is somewhat swollen, the lumen attains its maximum diameter. This swollen region involves about one-half of the entire spermatheca. The diameter decreases entad, the

swollen region merging gradually into the duct-like portion which extends obliquely across the cœlom to a point dorsad to the digestive tract, where it bends caudad. It meets and unites with the spermatheca of the opposite side in the posterior part of V, to form the large common duct which communicates with the digestive tract.

Henlea urbanensis n. sp.

(Pl. XII, Figs. 57–59)

Definition.—Length, 25 mm. Diameter, 0.57 mm. Color, whitish yellow. Prostomium blunt and rounded. Head pore at 0/I. Dorsal pores absent. Setæ of unequal length, the inner ones slightly shorter and finer; slightly bent; 6–8 (usually 8) in ventral bundles; 4–6 in lateral bundles. Clitellum on ½ XI–XIII. Lymphocytes elliptical, large. Brain about as wide as long; anterior margin concave, posterior margin emarginate; lateral margins divergent caudad. Peptonephridia present and well developed, connected with digestive tract in V; dorsal and ventral strands in close contact with digestive tract, both showing conspicuous thickenings at origin which extend freely into cœlom, the dorsal strand giving rise to tubules in VI, and the ventral to similar tubules in VI and VII. Two "taste organs" in buccal cavity. Œsophagus passes rather abruptly into intestine in VIII. Two lateral sac-like diverticula in VIII, the cavity of each communicating with lumen of digestive tract by one lateral opening. Dorsal vessel arises in IX. Nephridia with small anteseptal and large well-developed postseptal part, the efferent duct arising from ventral surface of latter near septum. Spermiducal funnel moderate, length about two and one third times greater than diameter. Spermatheca not strongly developed; no distinct ampulla; diameter greatest in region of external opening, where it is surrounded by a rosette of glands; communicates with lumen of digestive tract on dorsal side by means of a short channel formed by the fusion of the two spermathecæ at their ental ends; ectal opening laterad, near IV/V.

Described from one sexually mature specimen. Type in the collection of the writer.

The specimen which is the basis of this description was found in late March, 1911, near Urbana, Illinois, in the rich soil of undisturbed forest-land. The specimen is sexually mature, since it shows spermatozoa in the spermathecæ, well-developed egg masses in the body cavity, and developing spermatozoa in XI.

EXTERNAL CHARACTERS

The length of the type specimen is 25 mm. The body is long, slender, and in transverse section is circular in outline. The greatest diameter is in the region of the clitellum, where it measures 0.57 mm. The body is opaque and whitish yellow in the living specimen. Unfortunately the data concerning the number of somites have been lost, and therefore that point must remain unsettled until additional material is examined. The prostomium is rather blunt and rounded. The intersegmental grooves are rather indistinct. The shape and arrangement of the setæ are very much as in *Henlea moderata* but there is a distinct difference in the number of setæ per bundle. In the first thirteen somites the ventral bundles contain 6–8 setæ, usually the latter number; the lateral bundles contain 5–6, never more than 6. The mid region of the body usually has 7 setæ in each of the ventral bundles and 4–6 in the lateral bundles. The proximal ends of the setæ are distinctly bent.

INTERNAL CHARACTERS

Brain.—The brain is in I and II, chiefly in the latter. The length is about the same as the greatest width, the measurements being as follows: length, 0.146 mm.; greatest width, 0.142 mm. The posterior margin is distinctly emarginate and the anterior margin is quite concave. The smallest width (0.125 mm.) is in the region of the origin of the commissural trunks. From this point the lateral margins diverge caudad as far as the region of greatest width, which is about midway of the length of the organ. Thence the lateral margins round off gradually into the posterior margin. In transverse section the brain is elliptical in outline. One pair of supporting strands extends from the sides of the brain to the body wall; another pair extends from the two terminal lobes to the body wall.

Peptonephridia.—These organs are two rather complicated structures, one arising from the dorsal, and one from the ventral, surface of the alimentary canal, in the anterior part of V. They resemble those of *H. moderata* in the general plan of structure, but present certain marked differences. The dorsal and ventral peptonephridia are quite dissimilar. The dorsal one, at its origin, gives rise to two parts, one ental and the other ectal. The ectal part is a large, thick-walled, tubular structure, which extends into the body cavity. Immediately beyond its origin this ectal part assumes a position parallel to the digestive tract and extends caudad for about the length of one somite. The ental part has a very intimate relation to the wall of the digestive

tract, since it lies under the outer coat of the latter. Immediately anterior to the third pair of septal glands it gives rise to two irregular branching outgrowths, one on the right and one on the left side, which escape from the enclosing sheath of the digestive tract and extend freely into the cœlom, showing a tendency to lie in close proximity to the dorsal blood-vessel. The main part of the dorsal peptonephridium continues caudad, maintaining its intimate relation with the digestive tract, and ends just anterior to the origin of the intestinal diverticula. The ventral peptonephridium is also composed of two parts, one ental and the other ectal. The ectal part resembles the corresponding dorsal one in structure and mass, but differs in shape and distribution. Just beyond its origin it enlarges and extends into the body cavity. It is composed of two parts, one of which extends cephalad for a distance of about half a somite, forming about four fifths of the bulk of the structure, whereas the other extends caudad for a short distance. The former is unbranched. The ental part resembles the corresponding dorsal one in structure and in its relation to the digestive tract. Just anterior to the third pair of septal glands it gives off right and left branches which project freely into the body cavity, extending dorsad around the alimentary canal. These branches are in close proximity to the corresponding ones of the dorsal peptonephridium but do not unite with them. The main part of the ventral peptonephridium continues caudad, maintaining its intimate relation to the digestive tract up to a point just anterior to the intestinal diverticula, where it again gives rise to right and left branches which extend into the cœlom. These branches are similar to the corresponding anterior ones except that they are not so extensive. The main part of the gland, which is longer than the dorsal peptonephridium, ends just anterior to the origin of the intestinal diverticula. All of the various parts of the peptonephridia have essentially the same structure. They are rather thick-walled, tubular, and conspicuously nucleated. The peculiarly thickened portions at the origin of the glands vary from the other parts in staining capacity, and to some extent recall the peptonephridia in *H. leptodera* Vejd. as figured by Vejdovský ('79, Taf. X, Fig. 2).

Taste Organs.—A pair of these organs arise from the floor of the buccal cavity, one on each side of the median line, and extend out into the lumen. They are about 0.057 mm. long. The basal part of each is somewhat constricted, forming a sort of pedicel, and the remainder is spindle-shaped, thick in the middle and tapering to a point at the extremity. The body of each of these organs is composed of elongated, nucleated cells which resemble the other epithelial cells of the

lining of that part of the digestive tract in structure and staining reaction. The extremities are characterized by the disappearance of all traces of cell walls and nuclei, thus presenting a somewhat homogeneous appearance. The entire surface is covered by cuticula. Each organ is provided with a muscle which extends ventro-caudad from its base to the body wall.

Intestinal Diverticula.—The intestinal diverticula comprise two lateral sac-like evaginations which arise from the intestine in the posterior part of VIII. They extend cephalad from the point of origin and fill the greater part of the cœlom in that region. Their dimensions increase from the point of origin towards the anterior part of VIII. They are somewhat flattened laterally, the greatest diameter being in a dorso-ventral direction. The structure of these organs (Pl. XII, Fig. 59) is very interesting. Each diverticulum contains a large central cavity, a continuation of the lumen of the intestine, which communicates with it by a single, dorso-lateral, slit-like opening. Another of the characteristic features of the structure of this organ is the intricate folding of the inner lining. The dorsal portion of the side adjacent to the alimentary canal shows but little if any folding, but the entire opposite wall is conspicuously folded. This folding, which involves most of the thickness of the wall, occurs all along the ectal and ventral sides. Examination with high magnification shows a series of blood sinuses which are intimately related to the walls of the diverticula. In the anterior part of each organ they are inconspicuous, being confined to small spaces in the walls and folds. Towards the intestinal connection, however, they become more apparent, and occupy considerable space between the parts of the walls as well as the numerous spaces in the folds, as indicated in Figure 59. The spaces in the folds appear slit-like in transverse sections. The sinuses increase in size and diminish in numbers posteriorly until a few large sinuses result from the union of the smaller ones. Ultimately one very large sinus appears, which is the main channel of connection with the perivisceral sinus at the junction of the diverticulum with the intestine. The ectal surface of the diverticulum is to some extent covered with chloragog cells. The ental surface shows no such cells, but is covered with a peritoneal layer of the usual type. The wall of the diverticulum is composed of (1) an external peritoneum, either modified into chloragog cells or of the usual type, (2) a middle region, occupied by blood sinuses, and (3) an inner, rather thick, greatly folded, non-ciliated epithelium. Slightly cephalad to the junction of the diverticulum with the intestine, however, this epithelium begins to take on the appearance of the lining epithelium of the

intestine, becoming ciliated, and having also similar staining reaction. The staining reaction of the bulk of the diverticulum is quite different from that of the epithelial lining of the intestine, from which it originates. At the point of union of the diverticulum with the digestive tract there is a marked and abrupt increase in the diameter of the latter.

A comparison of the structure of these organs with that of the corresponding organs of *H. moderata* reveals a wide difference in the two species. In the latter a totally different plan of structure is found. It is not possible to make extensive comparisons owing to the meager treatment of the intestinal diverticula in the literature of other species of *Henlea*. Michaelsen ('86a) figures their structure in *H. leptodera* Vejd. and *H. ventriculosa* Udek., and both conform to the same general plan as that presented in *H. urbanensis*. They have one rather spacious central internal cavity bounded by walls which show infoldings, and which contain the blood sinuses in somewhat the same relation. However, they are quite different from those of *H. urbanensis* as indicated by the following facts:– H. *ventriculosa* has four diverticula, which, alone, distinguishes it from the other species. *H. leptodera* has two diverticula, but they differ from those of *H. urbanensis* since the folds in the inner lining are larger, and though much fewer in number are present on the ental as well as on the ectal wall. The branches of the blood sinus are also fewer. Michaelsen ('89) described and figured the structure of the intestinal diverticulum in *H. nasuta,* which also presents the same general type of structure as in *H. urbanensis* but has wider and more irregular folds of the lining membrane. The folds also show branching—a condition which does not appear in *H. urbanensis.* Furthermore, according to Michaelsen's figure there is in *H. nasuta* no difference in the structure of the ectal and ental walls. The distribution of the blood sinuses is somewhat similar. Eisen ('05, p. 100) makes the following brief statement concerning these organs in *H. californica*: "Intestinal pouches in VII are similar to those figured by Michaelsen from *H. nasuta.* The villi are fully as intricately folded." The same writer ('05, p. 102) makes the following meager statement concerning *H. guatemalæ*: "Intestinal pouches in VII; epithelium with comparatively few folds;" and, again, concerning *H. ehrhorni* he says ('05, p, 105): "Intestine.—The tubular part is furnished in VIII with a pair of diverticles which not only fill the largest part of VIII but also project into VII. The inner lobes of the diverticles are much coarser than in *H. californica,* the villi being less numerous and more of the nature of those of the diverticles of *Benhamia.* At the pos-

terior end of the diverticles there is a large valve opening into the sacculated intestine."

It does not appear from any information which can be gleaned from the literature on this subject that the structure of the intestinal diverticula in *H. urbanensis* is like that of any other species.

Dorsal Vessel.—The dorsal blood-vessel arises from the perivisceral blood sinus in IX. At its origin, and extending somewhat into VIII, is a very large heart-like expansion which in the specimen studied is filled with some substance—probably the remains of the blood. In the posterior part of VIII this swelling decreases rapidly and the dorsal vessel proper appears, lying near the mid-dorsal line of the alimentary canal. Immediately anterior to the third pair of septal glands there is another, but less prominent, expansion of the vessel. This also soon becomes reduced to the usual diameter. The greater part of the external surface of the vessel is covered by chloragog cells. The marked change in the diameter of the vessel in VIII is accompanied by marked changes in the walls of the vessel. In the anterior part of VIII the vessel is thick-walled, its external surface is covered with chloragog cells, its inner surface has a number of cells projecting radially into the lumen, and it is of the usual diameter. Near the middle of VIII there is a sudden change in which the diameter increases greatly, the wall decreases in thickness to a mere membrane, the chloragog cells are lost, and the only cells which can be identified in connection with the walls are the few cells which lie flattened against or are contained within the extremely thin wall.

Nephridia.—The anteseptal part is small, the postseptal part is large, broad, and somewhat pointed at the posterior extremity. The efferent duct arises from the postseptal part, near the septum, and usually is about as long as the former. The internal lumen is tortuous throughout its entire length. The right nephridium on XIII/XIV is missing. This is probably due to the fact that that side of the body is filled with developing egg-masses, this producing a crowded condition which has brought about the elimination of the nephridium.

Spermiducal Funnel.—The spermiducal funnel lies in the ventral part of XI with its base in close proximity to XI/XII. It lies close to the body wall and parallel to the long axis of the body. It is about two and a third times longer than the diameter, the length being 0.192 mm., and the diameter 0.085 mm. The sperm duct is long, much contorted, and confined to XII.

Penial Bulb.—This organ (Pl. XII, Fig. 58) is of the lumbricillid type of structure. It lies in the usual position in the ventral part of XII, on a deep invagination of the body wall. It is large in compari-

son to the size of the body, and is conspicuous in sections. The body of the bulb is composed of three kinds of cells. The first kind forms a series in which the cells are arranged radially around the penial lumen for its entire length. They are uniform in character and have but a slight staining reaction. The nuclei lie at the bases of the cells and are so regular in their distribution that they appear as a distinct row in sections. The cells of the second kind occupy the dorsal peripheral part of the bulb. They are fusiform, and arranged in such a way that the oval nuclei appear somewhat scattered. These cells are so placed that their long axes point towards the penial lumen. They stain deeply, and have the general appearance of gland cells. The third series of cells occupies the ventral ectal part of the bulb, lying between the inner bulb cells and the ventral periphery. They are much larger than the other kinds of cells and their boundaries are less strongly marked. Their contents as indicated by the staining reaction are quite distinct from the other cells, being less dense and taking the stain sparingly. The sperm duct enters the bulb on the ectal side not far from the lowest point of the penial invagination. It penetrates the bulb and meets the penial lumen at a point about half way between the dorsal periphery and the penial pore. The penial lumen curves laterad and meets the penial invagination in the upper half of its length. The cuticula which lines the invagination is also continued into the penial lumen as a lining. The bulb is covered by a musculature which is a continuation of the circular muscle layer of the body wall. From the inner extremity of the penial invagination a muscular strand extends diagonally dorsad and soon unites with the muscle layer of the body wall. The transition from clitellar cells to the bulb cells is very abrupt.

Ovaries.—The ovaries are massive, extending dorsad around the digestive tract. Egg masses are present in the cœlom, and the type specimen appears to be at the height of sexual maturity.

Spermathecæ.—A pair of these organs lie in V. The ectal opening of each is laterad and in the intersegmental groove IV/V, where it is surrounded by a rosette of glands (Pl. XII, Fig. 57). The diameter of each organ is greatest near the ectal opening, and from thence entad the diameter is reduced and becomes nearly uniform for the greater part of its length. There is no well-developed ampulla, and the spermatozoa are present all along the lumen. The spermatheca extends obliquely across the cœlom to the digestive tract, where it bends caudad. In the anterior part of V the two spermathecæ unite to form a single common lumen (Pl. XII, Fig. 57) through which both communicate with the digestive tract. This communication is not mid-dorsal as is usually the case, but is latero-dorsad in position.

LUMBRICILLUS Oersted

The name *Lumbricillus* was first used by Oersted in 1844, but was not given a permanent place in the nomenclature until 1900. Previous to that time the old name *Pachydrilus*, of Claparède, was in common use, but Michaelsen, finding that the name *Lumbricillus* antedated *Pachydrilus*, replaced the latter by *Lumbricillus*, which is now accepted by most workers in *Oligochæta*. The genus is defined by Michaelsen ('00, p. 78) as follows: "Kopfporus klein, zwischen Kopflappen und 1. Segm. Borsten S-förmig gebogen. Rückenporen fehlen. Blut gelb bis rot. Das Rückengefäss entspringt postclitellial und besitzt keinen Herzkörper. Peptonephridien fehlen. Hoden aus einer Anzahl birnförmiger Teilstücke bestehend. Samenleiter lang. Samentaschen ohne Divertikel." Eisen extends the above definition by adding points concerning the testes, nephridia, and penial bulb. His definition of the genus is as follows: "Setæ sigmoid, arranged in fan-shaped fascicles. Head pore small, situated between the prostomium and the peristomium. Brain generally deeply emarginated posteriorly. Ventral sexual glands around the ventral ganglion generally present. Blood red or yellow. Dorsal vessel rises posteriorly to the clitellum. No cardiac gland. No peptonephridia. Testes multilobed, each lobe capped by a small sperm sac. Sperm ducts comparatively narrow. Penial bulb without inner muscular strands, containing only numerous glands of various kinds, some of which may open into the basal part of the sperm duct. No atrium and no glands outside of the penial bulb. Nephridia with entire postseptal and with an anteseptal which consists merely of the nephrostome." The chief diagnostic characters are the absence of dorsal pores, peptonephridia, and cardiac gland, and the presence of sigmoid setæ and plurilobed testes. That the ventral glands ("Kopulationsdrüsen" of Michaelsen and Ude, "copulatory glands" and "outgrowths of the nerve cords" of Beddard, "ventral glands" of Eisen) are not diagnostic of the genus is made apparent by the fact that Southern ('09, pp. 149 and 158) found them in *Marionina semifusca* Clap. and *Enchytræus lobatus* Southern. Stephenson ('11, pp. 52, 58, 62) found them in *Enchytræus nodosus* Steph., and evidences of them in *Enchytræus sabulosus* Southern and *Fridericia bulbosa* Rosa. These glands are common to the genus but evidently not distinctive characters.

It has been recently shown that there is a close relationship between *Lumbricillus* and *Enchytræus*. Stephenson ('11) has found intermediate species which serve to bridge over the interval between the two genera. He described a new species from the Clyde, *Lumbricillus*

viridis, which is typically lumbricillid in all respects except that the setæ in the anterior part of the body have the form typical of *Enchytræus* and that in the posterior part they show only a faint double curve. He also described a new species from the same general locality, *Enchytræus nodosus,* which, though unquestionably an *Enchytræus,* has the following lumbricillid characters: ventral glands, a compact penial bulb, and, in certain cases, a slight double curve of the setæ. Again, *Enchytræus dubius,* a new species described from the same general locality, has setæ typical of the genus *Enchytræus* but has ventral glands, a compact penial bulb ("although it is bifid internally"), and lobed testes which resemble those in *Lumbricillus.* It also has red blood. It may be added that *Enchytræus albidus* Henle, a very typical species of that genus, has an imperfect penial bulb surrounded by other and smaller aggregations of gland cells. All of these facts are interesting, since heretofore these two genera have been regarded as standing some distance apart and have been placed in different subfamilies. This point will be discussed in greater detail in another connection (p. 178).

Michaelsen ('00) assigned seventeen species to this genus, one of which he regarded as somewhat doubtful. Later ('03b) he added *L. henkingi* Ude to the list, making a total of eighteen species, none of which had been reported from North America. Recent investigations have increased the number, so that at present thirty-one species, three varieties, one doubtful species, and one doubtful variety are assigned to this genus. Of this number six species and three varieties have been described from North America. They are as follows, the type locality being also given: *L. santæclaræ* Eisen (San Mateo County, California), *L. merriami* Eisen (Metlakatla, Alaska), *L. merriami,* var. *elongatus* Eisen (Metlakatla, Alaska), *L. annulatus* Eisen (Metlakatla, Alaska; also Orca, Prince William Sound), *L. ritteri* Eisen (Farragut Bay, Alaska), *L. franciscanus* Eisen (Santa Clara River, California), *L. franciscanus,* var. *borealis* Eisen (St. Paul Island, Pribilof group, Alaska), *L. franciscanus,* var. *unalaskæ* Eisen (Unalaska), and *L. agilis* Moore (Casco Bay, Me., to Vineyard Sound, Mass.). *L. rutilus,* n. sp., is described in the following pages.

Key to the Species of Lumbricillus known to occur in North America

1 (6) Spermatheca with crown of glands limited to the ectal opening.
2 (3) Spermathecal duct distinctly set off from ampulla; ventral glands in XIV–XV; brain two and one half times longer than wide, posterior margin deeply emarginate. . . . . *santæclaræ*
3 (2) Spermathecal duct not distinctly set off from ampulla.

4 (5) Ventral glands in XIII–XIV; brain one and one half times longer than wide, posterior margin distinctly emarginate; moderately developed clitellum on XII-XIII, incomplete on ventral side .... *rutilus*

5 (4) Ventral glands in III–V; brain, slightly longer than wide, posterior margin angular and deeply emarginate; clitellum thick and conspicuous, completely surrounding XI–XII...... *agilis*

6 (1) Spermatheca with glands covering entire length of duct.

7 (14) Spermatheca with distinct rosette of glands at ectal opening of duct.

8 (9) Spermathecal ampulla large, rounded, and distinctly differentiated; ventral glands in XIII–XVII, clitellum on ½ XI–XIII .... *ritteri*

9 (8) Spermathecal ampulla small and inconspicuous.

10 (13) Clitellum on ½ XI–XIV; ventral glands in XIV–XVII, all of uniform size.

11 (12) Ampulla small and conical, constituting about one third of the whole spermatheca; testes consisting of 12 to 15 lobes...... .... *merriami*

12 (11) Ampulla conical but larger, constituting approximately one half the length of spermatheca; testes with about 10 lobes...... .... *merriami*, var. *elongatus*

13 (10) Clitellum on ½ XI–½ XIV; ventral glands in XIV–XIX, small ones in III–X.......................... *annulatus*

14 (7) Spermatheca with no rosette of glands at ectal opening of duct.

15 (18) Setæ of a bundle of approximately uniform size.

16 (17) Ventral glands in XIV–XVI, moderate in size and not divided into lobes .... *franciscanus*

17 (16) Ventral glands in XIII–XIV, large, not divided into lobes.... .... *franciscanus*, var. *unalaskæ*

18 (15) Setæ of a bundle not of uniform size; ventral glands in XIII–XV, large, posterior two divided into a number of lobes.... .... *franciscanus*, var. *borealis*

LUMBRICILLUS RUTILUS n. sp.

(Pl. VIII, Fig. 13; Pl. IX, Figs. 14–24)

Definition.—Length, 15–19 mm. Diameter, 0.44–0.68 mm. Somites, 41–49. Color, red with slight tinge of yellow. Prostomium rather short and rounded. Head pore on 0/I. Dorsal pores absent. Setæ sigmoid; all of same size and approximately of same length; in anterior ⅔ to ¾ of body, 6–7 in lateral bundles, and 5–10 (usually 5–7) in ventral bundles; 2–4 in posterior part of body. Clitellum on XII–XIII, interrupted on mid-ventral surface. Brain about one and one-half times longer than wide; anterior margin concave, pos-

terior margin distinctly emarginate, lateral margins slightly divergent caudad. Peptonephridia lacking. Dorsal vessel varies slightly in position of origin, arising in XIII–XIV. Nephridia with large postseptal part and very small anteseptal part which consists only of nephrostome; efferent duct arises from ventral surface of posterior part of postseptal part. Testes multilobed, with about nine lobes on each side of body; each lobe capped by a small sperm sac. Spermiducal funnel cylindrical, four to five times longer than diameter, and strongly bent at middle; collar present, slightly reflected, slightly wavy in outline, and set off from body of funnel by slight constriction. One pair of spermathecæ in V; without diverticula and each consisting of a well-developed ampulla and a short duct; ampulla consisting of an expanded, barrel-shaped, thick-walled and much narrower ental region which is reflected cephalad before uniting with digestive tract; duct not sharply set off from ampulla, much shorter than ampulla and surrounded by well-developed gland which shows a number of lobes arranged in form of rosette; ectal opening laterad and near IV/V, ental opening on lateral wall of digestive tract in posterior part of V. Ventral glands in XIII and XIV; differ slightly in shape in the two somites; surround ventral ganglia closely on ventral, lateral, and part of dorsal surfaces, leaving only median dorsal line free.

Described from thirty-two sexually mature specimens. Many other specimens were examined in determining external characters. Type and paratypes in the collection of the writer, and paratypes in the collection of Professor Frank Smith.

The specimens which are the basis of this description were collected June 22, 1911, by A. A. Girault, in sprinkling filter No. 5 of the Chicago Sewage Testing Station. They occurred in great abundance in the sludge which covered the limestone rocks composing the filter bed. A complete description of the habitat of these worms is given in another part of this paper (pp. 180–184).

Affinities.—This form is easily separated from the other known American species, and the differences are so distinct and so numerous that it can scarcely be said to have any close relatives among the American forms. When compared with the foreign species of this genus it appears to resemble *L. litoreus* Hesse, *L. subterraneus* Vejd., *L. lineatus* Müll., *L. verrucosus* Clap., and *L. tenuis* Ude. There are, however, a number of distinct differences in each case and, furthermore, the descriptions of the above-named species are very brief and make no reference to some characters which are now considered to be of use in separating species. When these descriptions are made more complete it is reasonable to expect that other points of difference not yet known will be found.

EXTERNAL CHARACTERS

The body is smooth, slender, cylindrical, and tapers gradually towards the two extremities. The length in alcoholic specimens varied from 9 to 14 mm., the more common length being 10 to 12 mm., but in a series of measurements of mature living specimens not extremely contracted or elongated, the length was found to vary from 15 to 19 mm. The lower range of alcoholic specimens is probably due to the effect of the fixing fluid. The diameter in alcoholic specimens is greatest in the region of the clitellum, where it is 0.446–0.684 mm. The first five to nine intersegmental grooves are very distinct, but the others are rather obscure. The number of somites is variable, but the limits of the variation are quite narrow, counts in thirty-five specimens ranging only from 41 to 49. The moderately developed clitellum is on XII–XIII and occurs only on the dorsal and lateral surfaces of the worm. In alcoholic specimens the body is opaque, and light brown except on the clitellum, where the color is much fainter. The living animal is reddish with a slight tinge of yellow. The prostomium is blunt, smooth, and rounded. The setæ (Pl. IX, Fig. 21) are distinctly sigmoid, and are arranged in fan-shaped bundles. The bundles are disposed in four longitudinal rows, two ventral and two lateral. In the ventral rows the number of setæ per bundle varies from 4 to 8, being occasionally 9 and in rare instances 10. In the lateral rows the number varies from 4 to 7. On the last few somites the number in both sets of rows varies from 2 to 4.

INTERNAL CHARACTERS

Brain.—The brain (Pl. IX, Fig. 22) lies in I and II. The length is about one and one-half times the width. The posterior margin is distinctly emarginate; the anterior concave. The lateral margins vary to some extent, being in some cases nearly parallel, in others slightly divergent caudad. Two pairs of supporting strands extend from the posterior end of the brain to the body wall, while from the anterior end a rather strong muscular strand extends from the mid-ventral region to the wall of the prostomium.

Blood Vascular System.—Since the blood in this species is colored and the vessels are rather large, remaining distended after death, it has been possible to follow out the course of the chief vessels. Furthermore, owing to the fact that the integument of the body is semitransparent, permitting the blood-vessels to stand out prominently, it was possible to study the vascular system in the living form and thus to verify the observations made on the alcoholic material.

The system (Pl. VIII, Fig. 13) consists of two principal longitudinal vessels, one dorsal and one ventral, and transverse vessels which connect them in the anterior region. The dorsal vessel arises from the perivisceral sinus in XIII–XIV. An examination of twenty specimens showed that the origin of this vessel is not constant in position and that it varies within the limits of XIII–XIV. In the majority of cases the origin is at XIII/XIV. In the intersegmental regions this vessel shows constrictions which are slight in its anterior part but distinct in its posterior half. Distinct swellings are present in XI, XII, and XIII. From its origin the dorsal vessel extends cephalad, parallel and dorsal to the digestive tract, and throughout its course it maintains a rather close relation to it. In I this vessel divides into two symmetrical branches, one of which passes around the right side and the other around the left side of the digestive tract. These branches extend to the ventral side of the buccal cavity and each comes to lie parallel to it, thus forming the right and left ventral trunks. They extend caudad into IV, where they approach each other and unite, thus forming a single vessel which extends to the posterior region of the body. In III a branch extends dorsad from each of the ventral vessels to connect with the dorsal vessel at a corresponding point, thus forming the first pair of transverse vessels. The second pair of transverse vessels is in IV, anterior to the point of union of the two ventral vessels. The third pair is united with the ventral vessel very near IV/V and immediately posterior to the point of union of the right and left ventral vessels and extends to the dorsal vessel, uniting with the latter near the corresponding point of union of the second pair of transverse vessels. The fourth pair connects the dorsal and the ventral blood vessels in V.

Nephridia.—The nephridia (Pl. IX, Fig. 15) are of the usual lumbricillid type in which the postseptal part is greatly developed but the anteseptal part is represented only by the nephrostome. The efferent duct arises from the ventral surface of the posterior end of the postseptal part, and opens to the exterior in front of the ventral setæ.

Testes.—The testes are in the usual position in XI and are multilobed. Each lobe is club-shaped, and its attachment to the ventral surface of X/XI is very slender. There are approximately 8–10 of these lobes on each side of the digestive tract, all somewhat similar in size and shape, and radiating fanwise from the point of common attachment, the anterior and the posterior ones extending out into the adjacent somites. Each lobe is capped by a sperm sac.

Spermiducal Funnel.—This organ (Pl. IX, Figs. 14, 17) lies in the usual position in XI. The length is about four to five times the

diameter. In all of the specimens examined the funnels are cylindrical and strongly bent near the middle, usually reflected upon themselves. The collar at the anterior end of the funnel is usually somewhat wavy in outline and varies in shape, being sometimes slightly reflected and sometimes flaring. The duct extends through XI/XII, and after a few contortions, extends directly to the penial bulb.

Southern ('09, p. 149) claims that the sperm funnel in the genus *Lumbricillus* is "very contractile" and "varies greatly" in its relative proportions according to the amount of tension on it. He holds that "specific determinations, therefore, which rely on these two characters [the funnel and the ventral glands], must be regarded with suspicion, especially when preserved material has been used." No evidence of such variation has been found in *L. rutilus*—at least not enough to warrant so strong a statement as the above. It is quite doubtful if the spermiducal funnel in *L. rutilus* is "very contractile," since its structure is such as to preclude exceptional contractility. The muscular tissue is reduced almost to a minimum, and since the bulk of the organ is composed of long, closely set cells and the lumen is very fine it does not appear reasonable to expect great contractility in the funnel of this species.

Penial Bulb.—This organ (Pl. IX, Fig. 24) is rather simple in its structure and conforms to the lumbricillid type. It is rather large as compared with the diameter of the body, is approximately globular in shape, and is covered by a musculature which is a reflection of the musculature of the body wall. This muscular covering is composed of both the circular and longitudinal layers. The circular muscles lie in contact with the gland cells of the bulb and are very much reduced in thickness, so much so that it is difficult to demonstrate them with high powers. However, close observation shows that there is a very thin layer present, and in transverse sections it is easy to distinguish strands of muscle fibers passing from the circular layer of the body wall to the periphery of the bulb in two different regions; namely, between the entrance of the sperm duct and the body wall, and between the periphery of the bulb and the ventral body wall. The longitudinal layer is well developed, and in transverse sections it shows the same structure as that of the body wall, the only difference being a reduction in thickness. The interior of the bulb is filled with cells of but one kind. These cells differ somewhat in shape in the different parts of the bulb, but in general they are elongate, somewhat uniform, and most of them are arranged radially around the penial lumen. The nuclei are located for the most part in the peripheral ends of the cells. The peripheral part of each cell stains deeply, while the opposite

part, which is approximated to the penial lumen, stains lightly. At the ventral side of the bulb the cells merge gradually into the hypodermis of the body wall. The sperm duct meets the dorsal part of the bulb near the lateral body wall, and unites with the bulb in such a way that the terminus appears to be imbedded in the periphery of the bulb. In most cases this union is nearest the posterior part of the bulb. There is no differentiation between the sperm duct and the penial lumen, and it is a little difficult to determine the exact junction of the two. As the junction of the sperm duct with the bulb is slightly posterior, the penial lumen follows a cephalo-ventro-lateral course in reaching the exterior. The cuticula is reflected into the penial lumen and lines it for its entire length.

Spermathecæ.—A pair of these organs (Pl. IX, Fig. 16) is present in V. There is no well-defined line of separation between the duct and the ampulla. The ectal opening has a well-developed crown gland showing a series of emarginations on the ental margin, which gives it the appearance of having about six lobes. This gland is large enough to completely hide the spermathecal duct, since the ental periphery of the gland extends to the ampulla. The duct gradually merges into the ampulla, a fusiform region constituting the greater part of the mass of the spermatheca. The ental region of the ampulla gradually becomes reduced in diameter, forming a sort of duct-like terminus which has approximately the same length and diameter as the spermathecal duct. This ental part of the ampulla bends cephalad and unites with the digestive tract. This union is lateral in position and exactly opposite the corresponding opening of the other spermatheca. An examination of sexually immature specimens shows that the spermatheca lacks connection with the digestive tract,—a fact which seems to point to the conclusion that the ental part of the ampulla is the last part to be acquired by the developing spermatheca. The ectal opening of each spermatheca is surrounded by a thickened region of the hypodermis.

The abundance of material and its perfect histological condition has made it possible to study in some detail the histology of the spermathecæ. A number of interesting structural features are present and seem worthy of extended discussion, since the meager treatment of the structure of the spermathecæ in species of *Lumbricillus* gives no hint as to whether the condition in this species is unique or common to the group.

The wall of the ampulla (Pl. IX, Fig. 23) is composed of three layers, the enveloping peritoneum, the muscle layer, and the lining epithelium. The peritoneum is of the usual type, being merely a thin

membrane with scattered nuclei. The muscle layer is well developed, and consists of a single layer in which the component fibers extend around the organ in a transverse direction, thus forming a circular layer. It is about equally developed in all parts of the ampulla, and in the region of the junction with the digestive tract this layer passes over into the muscle layers of the latter. It is, however, very difficult to determine the exact structure of this transitional region, and the writer has not been able to demonstrate with absolute certainty to which of the muscle layers of the digestive tract it becomes allied. It seems to pass into the circular layer, as one would expect, and further evidence in support of this conclusion will be given later, when it will be shown that this muscle layer connects with the circular layer of the body wall. The epithelial layer of the ampulla constitutes the greater part of the mass of the organ. It is composed of tall, columnar cells, set closely together and distinctly nucleated at their bases. In all parts of the organ this layer is thick, and especially so in the enlarged part, where it is particularly thick and heavy, and the length of its component cells is many times greater than their diameters. This is a one-celled layer. In longitudinal sections of the ampulla this fact is clear enough in the ental region, where the ampulla connects with the digestive tract, but in the swollen region, where the layer has its maximum thickness, it appears at first sight to be composed of more than one layer of cells since more than one row of nuclei appear in the same section. These cells are, however, closely set, and sections of the usual thickness include parts of from two to three superimposed layers, thus giving the appearance referred to above.

The part of the spermatheca extending from the ampulla to the external opening is really the duct but is not sharply set off from the ampulla. It has a rather peculiar structure. The epithelial layer which lines the ampulla is interrupted completely, and the wall of the duct is composed of two kinds of elements only, the muscle layer, and the gland cells of the large gland which surrounds that region. This gland is composed exclusively of very long cells which extend from the periphery to the lumen of the duct. The nuclei are situated in the peripheral ends. In a longitudinal section of the spermatheca these cells have the appearance of having their inner ends cut off by a band of muscle tissue which separates this glandular region into two parts, one part lying between the lumen and the muscle band and the other lying beyond the latter. This appearance is further emphasized by the fact that the tissue outside of the muscle band stains readily, while that between the muscle band and the lumen does not take the

stain at all. In reality, these apparent regions are not distinct, the gland cells being continuous from the periphery of the gland to the lumen, with no interruption by the muscle band, as will be shown in the next paragraph.

The muscle elements in the spermathecal duct exhibit an interesting peculiarity in arrangement and derivation. At the ectal end of the ampulla the well-developed circular muscle-layer instead of continuing over the duct unchanged becomes converted into a series of muscle bands which extend at right angles to the direction taken by the fibers of the same layer on the ampulla. These bands do not form a continuous layer but occur at intervals, thus forming a cylinder of muscle bands, each of which is separated from the neighboring ones by spaces through which extend the prolongations of the gland cells to meet the lumen. These muscle bands continue through to the external hypodermis and become allied with the circular muscle layer of the body wall. Each band appears to be composed of two similar parts closely approximated, and in all cases this double condition of the bands seems to be constant.

Ventral Glands.—The peculiar and problematical organs which have been given several names ("Kopulationsdrüsen" of Michaelsen and Ude, "copulatory glands" and "outgrowths of the ventral nerve cord" of Beddard, "ventral glands" of Eisen) are present in specimens of this species. They are moderately developed (Pl. IX, Fig. 20) and are closely and uniformly associated with the ventral nerve cord in XIII and XIV. They almost completely surround the ventral ganglia, leaving only a small free space on the dorsal median line of the nerve trunk. In transverse section (Pl. IX, Figs. 18, 19) they appear to be made up of a mass of distinctly nucleated spindle-shaped gland cells which lie parallel to each other and extend ventrad. They do not have the lateral wing-like developments which are present in some species, but are compact and bulbous in appearance. Each penetrates the body wall in the mid-ventral region immediately under the nerve cord, thus opening to the exterior. In the majority of the specimens examined these glands are not bilaterally symmetrical but one side is more strikingly developed than the other, giving the whole the appearance of being turned over to one side. In all of the specimens examined the greatest development uniformly occurred on the same side in both glands, but in some individuals it was found on the left side, while in others it was on the right. The two glands differ but little in size but there is a difference in shape. The ental ends of the gland in XIII extend above the level of the ventral ganglion, forming a mid-dorsal fossa, while the ental ends of the one in XIV do not thus extend, and a fossa is not formed.

It appears that in the past undue stress may have been placed on the importance of the ventral glands as a specific character in the genus *Lumbricillus* and also in *Marionina*. Southern ('09, p. 149) has found great variation in them. "In some cases individuals have shown well-developed glands, whilst in others from the same locality they were either small, absent, or in different segments." Ditlevsen ('04, p. 433) also throws doubt on the value of this character in the separation of species. No evidence of variation has been observed in the ventral glands of *L. rutilus*. In every specimen of the long series examined they occur uniformly in XIII and XIV and in all cases showed practically the same degree of development. The only variable feature is that the greatest development in these asymmetrical glands occurs on the right side in some specimens and on the left side in others.

FRIDERICIA Michaelsen

Fridericia is a well-defined genus, separated from the other genera by the following important characters: the presence of dorsal pores, and the size and arrangement of the setæ. The setæ are produced in pairs in each bundle, the setæ of the outer pair being the largest, the next smaller pair being immediately within the largest, and these in turn inclosing still smaller ones in the same manner. The group thus formed is fan-shaped, with a pair of large outer setæ and gradating pairs between. Sometimes setæ fall out, thus destroying the symmetry of the bundle.

Michaelsen ('00, p. 94) defines the genus as follows: "Borsten in 4 Bündeln, gerade, zu 2 im Bündel und dann gleich lang oder zu mehreren und dann die inneren des Bündels mehr oder weniger regelmässig paarweise und stufenweise kleiner als die äusseren. Rückenporen mit Verschlusszellen meist vom 7., selten vom 6. Segm. an vorhanden; Kopfporus meist klein, dorsal zwischen Kopflappen und 1. Segm. Lymphkörper von zweierlei Gestalt. Peptonephridien stets vorhanden. Der Oesophagus geht allmählich in den Mitteldarm über. Das Rückengefäss entspringt meist postclitellial; Blut farblos. Nephridien meist mit grossem Anteseptale, in dem der Flimmerkanal schon Windungen beschreibt. Samenleiter lang. Samentaschen meist mit dem Darm kommunizierend, einfach oder mit Divertikeln."

Fridericia is the largest genus of the family *Enchytræidæ*. In 1900, Michaelsen recognized twenty-one species, and since that time the number has increased considerably, so that at present there are about ninety species referred to this genus. It appears that at least three of these species are doubtful. Sixteen species have been described

from North America, although Michaelsen ('00, p. 96) regards *F. parva* Moore as a synonym of *F. bulbosa* Rosa. The North American species with their type localities are as follows: *F. alba* Moore (Philadelphia, Pa.), *F. agricola* Moore (Philadelphia, Pa.), *F. longa* Moore (Philadelphia, Pa.), *F. parva* Moore (=*F. bulbosa* Rosa?) (Philadelphia, Pa.), *F. agilis* Smith (Havana, Ill.), *F. firma* Smith & Welch (Urbana, Ill.), *F. tenera* Smith & Welch (Urbana, Ill.), *F. harrimani* Eisen (Mountain View, Calif.), *F. fuchsi* Eisen (Santa Cruz, near Boulder Creek, Calif.), *F. johnsoni* Eisen (Santa Barbara, Calif.), *F. santærosæ* Eisen (Santa Rosa, Sonoma Co., Calif.), *F. santæbarbaræ* Eisen (Santa Barbara, Calif.), *F. macgregori* Eisen (Napa Co., Calif.), *F. sonoræ* Eisen (Sonora, Mexico), *F. popofiana* Eisen (Popof Island, Alaska), and *F. californica* Eisen (San Francisco, Calif.). Three new species are described in the following pages, namely, *F. douglasensis, F. oconeensis,* and *F. sima.*

Key to the Species of Friderica known to occur in North America

1 (14) Spermathecæ without diverticula.
2 (7) Posterior margin of brain convex.
3 (4) Spermathecæ do not connect with digestive tract........*sonoræ*
4 (3) Spermathecæ connect with digestive tract.
5 (6) Peptonephridia simple and unbranched; brain about twice as long as wide..*sima*
6 (5) Peptonephridia with four to six branches projecting from a common base; brain almost circular.................*fuchsi*
7 (2) Posterior margin of brain truncate or concave.
8 (9) Peptonephridia simple and unbranched.................*parva*
9 (8) Peptonephridia with distinct branches.
10 (11) Length over 10 mm.; somites over 50; dorsal pores begin on VI; dorsal vessel arises in XXII......................*alba*
11 (10) Length under 10 mm.; somites not more than 50; dorsal pores begin on VII.
12 (13) Dorsal vessel arises in XIV; peptonephridia short, each with at least two branches; brain deltoid, posterior margin almost straight, anterior margin conical.................*harrimani*
13 (12) Dorsal vessel arises in XIII; peptonephridia thick and compact, with the free end frayed; brain with the posterior margin slightly concave, anterior margin convex...........*johnsoni*
14 (1) Spermathecæ with diverticula.
15 (22) Spermathecæ each with two diverticula.

16 (17) Brain circular .... *santærosæ**
17 (16) Brain distinctly longer than broad.
18 (21) Spermathecal diverticula subcylindrical, no glands at ectal opening of duct.
19 (20) Length 20–25 mm.; somites, 65; anteseptal part of nephridia ovate, postseptal part slender, with a dorsal lobe about same size as anteseptal part.......................... *agricola*†
20 (19) Length 10–12 mm.; somites about 55; nephridia large, anteseptal part large and swollen and filled with opaque granules .... *santæbarbaræ*
21 (18) Spermathecal diverticula finger-like and pendent; two glands at the ectal opening of spermathecal duct.......... *popofiana*
22 (15) Spermathecæ with more than two diverticula.
23 (26) Peptonephridia simple and unbranched.
24 (25) Brain two thirds as broad as long, posterior margin convex; unicellular glands at ectal opening of spermathecal duct; length 25–30 mm.; somites, 60–69.................. *longa*
25 (24) Brain one and two thirds times longer than broad, angular, posterior margin truncate; no glands at ectal opening of the spermathecal duct; length, 11–20; somites, 43–55 *douglasensis*
26 (23) Peptonephridia with distinct branches.
27 (28) Two setæ per bundle, rarely three or four; nephridial duct arises from caudal end of postseptal part............ *agilis*
28 (27) Setæ predominantly four or more per bundle; nephridial duct arises from the anterior end of the postseptal part.
29 (32) Anterior margin of the brain concave.
30 (31) Length, 24–33 mm.; somites, 62–67; spermathecæ with 3–4 diverticula; no glands at the ectal opening of the spermathecal duct .... *firma*
31 (30) Length, 9–17 mm.; somites, 52–59; spermathecæ with 7 diverticula; glands present at the ectal opening of the spermathecal duct .... *tenera*
32 (29) Anterior margin of the brain convex.
33 (34) Branches of the peptonephridia arise from a common base; length, 8 mm. .... *macgregori*
34 (33) Branches of the peptonephridia arise dendritically and not from a common base; length over 8 mm.
35 (36) Dorsal vessel arises in XX....................... *oconeensis*
36 (35) Dorsal vessel arises in XVI...................... *californica*

*Spermathecæ as a rule with only two large diverticula, as the key indicates; but in one specimen Eisen found that the large diverticulum was replaced on one side by three smaller ones.

†A variety of this species has the terminal portion of the spermatheca glandularly thickened for a short distance from the mouth and one or two solid outgrowths alternating from the accessory sacs.

Fridericia douglasensis n. sp.

(Pl. IX, Figs. 25, 26; Pl. X, Figs. 27–34)

Definition.—Length, 11–20 mm. Diameter, 0.45–0.54 mm. Somites, 43–55. Color, white. Prostomium short, blunt, and slightly angular at tip. Dorsal pores begin on VII. Setæ, 3–6 per bundle in ventral rows and 3–5 in lateral rows in anterior part of the body; 3–6 in middle part, and 2–3 in posterior part. Clitellum on ⅓ XI–½ XIII. Lymphocytes elliptical. Brain about one and two thirds times longer than wide; anterior margin concave, posterior margin truncate, lateral margins divergent caudad for greater part of length of brain, then change abruptly to convergent caudad. Peptonephridia large, tubular, slightly tuberculate, unbranched. Dorsal vessel arises in XX. Nephridia with anteseptal and postseptal parts about the same size; efferent duct arises from middle of latter. Spermiducal funnel well-developed; length about one and one half times diameter; collar distinctly set off from body of funnel by constriction; margin of collar not reflected. Sperm duct shorter than in most species and with few contortions. Spermathecæ with duct, ampulla, and diverticula; ampulla funnel-shaped, with 7–11 globular, unequal, irregularly disposed diverticula; no glands at ectal opening of duct; each ampulla with independent connection with digestive tract.

Described from sixteen sexually mature specimens. Many more were examined in estimating the external characters. Type and paratypes in the collection of the writer, and paratypes in the collection of Professor Frank Smith.

The specimens on which this description is based were collected in a deciduous forest near the north shore of Douglas Lake, Michigan, July 14, 1911. They were found in considerable abundance under chips, pieces of bark, and other debris, at the base of a large fallen tree where considerable moisture was present.

Affinities.—The species belongs in the group having more than two diverticula on the spermathecæ. It appears to have no close relatives among the foreign species and is also distinct from the other American species, apparently approaching none of them closely unless it be *F. longa* Moore, the description of which is, however, too inadequate to make the establishment of relationships certain.

EXTERNAL CHARACTERS

The body is slender and has a length of 11–20 mm. In transverse section its outline is circular, and the diameter is greatest in the region of the clitellum, where it is 0.45–0.54 mm. The living specimens are

opaque and whitish. The intersegmental grooves are obscure for almost the entire length of the body; only the first two or three being at all distinct. In nearly all of the specimens examined the first intersegmental groove is deeply marked. The number of somites is variable, the extremes in a count of nine specimens being 43–55. The prostomium is short and slightly angular at the extremity. The degree of this angularity is slightly variable, but all of the specimens show it to some extent. The clitellum is moderately developed and is situated on ⅓ XI–½ XIII. The number of setæ per bundle varies in the different regions of the body and to a limited extent in the different rows. In general there are 3–6 per bundle in the ventral rows in the anterior region (more often 5 or 6), and 3–5 in the lateral rows; 3–6 in the middle region in both sets of rows; and 2–3 in the posterior region. Aside from a decided bend at the proximal end (Pl. X, Fig. 30) each seta is straight.

INTERNAL CHARACTERS

Brain.—This organ (Pl. X, Fig. 31) lies in I and II, chiefly in the latter. The anterior margin is concave, while the posterior margin is distinctly truncate. The lateral margins diverge caudad for about two thirds of their length. Figure 31 shows the characteristic shape of this organ. In transverse sections it is broadly elliptical in outline. The entire organ is surrounded by a well-developed neurilemma which is somewhat thickened between the roots of the commissural trunks. Two sets of supporting strands attach the posterior region to the body wall.

Peptonephridia.—There is a pair of these organs ventrad to the digestive tract, one on the right side and one on the left. Each opens separately into the alimentary canal in a latero-ventral position in IV. There is some variation as to the exact place of opening, some specimens showing it near the middle of IV while in others it is in the posterior part of IV. However, in all cases the opening occurs in IV. These organs (Pl. X, Fig. 34) are long and unbranched. They are tubular, with but a single lumen, which is large in comparison to the size of the organ. Immediately beyond the union with the digestive tract each peptonephridium turns abruptly caudad and extends parallel to it. The length varies somewhat in the various specimens. In some cases they extend into VI but in others only into V. Sometimes the terminal parts extend around the alimentary canal and end dorsad to it. One of the specimens examined, showed a peculiar condition in which one of the organs, about midway of its length, gave rise to a single,

long, well-developed branch which extended cephalad and terminated anterior to the opening of the peptonephridium. The structure of this branch is identical with that of the main trunk. This is probably an accidental condition, since it occurred in only one specimen and only on one side.

Chylus Cells.—The chylus cell region of the intestine occupies XV–XVIII in all of the specimens examined except one, in which a few chylus cells appear in the posterior part of XIV. Cells of two kinds are present (Pl. X, Fig. 33), the chylus cells and the ental epithelial cells. The chylus cells form a continuous layer. They are flask-shaped, the broader ends being ectad. The base of each is more or less truncate and the sides converge gradually entad. The apical half of the intracellular canal is straight, but the basal half is spiral and appears sigmoid in section. This intracellular canal is lined by a relatively thick specialized layer of cytoplasm which is everywhere uniform in thickness and structure. The canal is ciliated for the greater part of its length. The blood sinus comes in contact with little more than the basal end of each chylus cell. The ental epithelial cells are long and trumpet-shaped, the broad end being ental. Their ectal ends are inserted between the apices of the chylus cells. In longitudinal sections usually but one epithelial cell appears between each chylus cell and its neighbor. The ental surface of these cells is ciliated. Interstitial cells are absent. There appears to be a distinct difference in the structure of the chylus cells and the ental epithelial cells as indicated by the staining reaction. In the former the cytoplasm is somewhat granular, while the cytoplasm of the ental epithelial cells is more homogeneous and more dense.

Blood Vascular System.—The blood-vessels in the specimens of this species remain better distended than in the others examined, making it possible to follow them and to study the chief vessels. The system (Pl. IX, Fig. 25) consists of the usual dorsal longitudinal vessel, the ventral vessel, and the transverse vessels which connect them, these latter forming loops around the anterior part of the digestive tract. The dorsal vessel arises from the perivisceral blood sinus in XX. It shows distinct enlargements in each of the somites posterior to the clitellum. From its origin it extends cephalad, parallel to the digestive tract, with which it maintains a more or less close relation throughout its course. In the anterior region it lies between the brain and the buccal cavity, and is so reduced in diameter that it requires high magnification to follow it. At a point immediately under the anterior part of the brain it divides into two trunks, one passing to the right and the other to the left of the digestive tract, and both ex-

tending to the ventral side of the buccal cavity, where they lie parallel to it. These extend caudad to the anterior part of IV where they approach each other and unite near IV/V to form the single ventral trunk. Near the middle of III a transverse vessel extends dorsad from each ventral vessel and unites with the dorsal vessel near the posterior part of III. In the anterior part of IV similar transverse vessels connect the ventral vessels with the dorsal trunk. No transverse vessels occur in II.

Nephridia.—The anteseptal part (Pl. X, Fig. 27) is about the same size as the postseptal though there is a slight variation, the latter being sometimes a little larger than the former. The efferent duct arises from the mid-ventral surface of the postseptal part about midway of its length and opens to the exterior just anterior to the ventral setæ bundles of the same somite. The lumen is very tortuous throughout its entire course.

Spermiducal Funnel.—This organ (Pl. X, Fig. 29) lies in the usual position in XI with its base close to the ventral surface of X/XI. Its length is about one and one half times greater than its diameter. It is slightly bent, and in the majority of the specimens examined it was bent in such a way that the anterior end was directed dorsad or laterad. The collar is distinctly set off from the body of the funnel by a constriction. The diameter is only about one half that of the funnel. The free margin of the collar is not reflected but projects towards the developing sperm mass. The sperm duct is confined to XII. It seems to be much shorter than is usual in other species. Instead of the mass of convolutions generally present in XII there are at most but three or four coils, and from these the duct extends directly to the penial bulb.

Penial Bulb.—In structure the penial bulb (Pl. X, Fig. 32) conforms to the lumbricillid type as defined by Eisen. It is well developed, and is conspicuous in transverse sections of the body through XII. It is completely invested by a strong musculature which ultimately connects with the muscle layer of the body wall. When the bulb is completely retracted the penial invagination is large, having a depth equal to the length of the bulb. The sperm duct meets the bulb on the dorso-ectal surface and pentrates it for a short distance. Within the bulb it is replaced by the penial lumen which, curving broadly laterad, extends to the penial invagination, opening into the latter about midway of its depth. The cuticula lines the invagination and also extends into the penial lumen as a lining. The bulb is composed of two groups of cells. One group occupies the dorsal part of the organ, and is composed of cells which occur near the periphery but

send long extensions to the penial lumen. The second group of cells occupies the ventral part of the bulb, and opens on to the surface of the penial invagination. In nearly all of the preparations studied in this connection it was not difficult to determine the line of separation between these two groups of cells owing to the fact that they tend to separate and produce a distinct split in the bulb at that place.

All of the preparations examined, showed a few nuclei scattered among the extensions of the dorsal cells at a position about half-way between the periphery and the penial lumen. This recalls the fact that in *F. firma, F. agilis, F. agricola,* and in other species, there is a group of cells between the penial lumen and the peripheral dorsal cells which is conspicuous in sections because of the arrangement of the numerous similar nuclei in a definite row. Critical examination of this bulb has failed to reveal a third definite group of cells in this organ. High magnification shows that the scattering nuclei represent only occasional cells interpolated between the extensions of the other cells. It is possible that the structure of this bulb represents a transition between the type represented by *F. firma* and that represented by *F. tenera.*

Spermathecæ.—A rather surprising variation exists in these organs in the different specimens. In order to be sure of sexual maturity each spermatheca was examined carefully for spermatozoa, their presence being taken as evidence that the specimen was sexually mature. The number of diverticula (Pl. X, Fig. 28) varies from about 7 to 11. They are of unequal size on the same spermatheca, and their number may vary in members of the same pair. They are more or less spherical, and the cavity of each has a wide communication with the lumen of the ampulla. In some cases the diverticula are quite distinct; in others they are so obscure that at first sight there seems to be none, but closer examination shows that they are uniformly present. The ampulla is pear-shaped and connected with the digestive tract. There is considerable variation in the position of this connection. In some specimens it is near the mid-dorsal line and the ental ends of the two ampullæ lie so closely together that only very careful examination of sections reveals the fact that they enter separately. In other specimens the ampullæ unite with the digestive tract laterally, one exactly opposite the other. Furthermore, there is some variation in the way in which they approach the digestive tract. They may approach similarly, or the ampulla on one side may curve dorsad and unite with the digestive tract near the mid-dorsal line, while the other extends directly to the mid-lateral surface and unites at that point. The spermathecal duct is straight and its ectal opening is devoid of glands.

FRIDERICIA OCONEENSIS n. sp.

(Pl. X, Figs. 35–37; Pl. XI, Figs. 38–42)

Definition.—Length, 13–17 mm. Diameter, 0.34–0.43 mm. Somites, 44–60. Color, whitish. Prostomium blunt and rounded. Dorsal pores begin on VII. Setæ of unequal length, inner ones finer and shorter; almost straight except for distinct bend at proximal end; 4–6 per bundle for almost entire length of body, sometimes as many as 8 per bundle; 1–4 per bundle in last few somites. Clitellum on XII–XIII. Lymphocytes numerous, elliptical to circular in outline. Brain about twice as long as wide; posterior margin distinctly convex; anterior margin slightly convex; lateral margins divergent caudad. Peptonephridia long, tuberculate, with but few branches, which arise irregularly along main part of each organ. Dorsal vessel arises in XX. Nephridia with anteseptal and postseptal parts of about same size; efferent duct arises from anterior part of latter near septum. Spermiducal funnel with length about twice the diameter, cylindrical, bent near posterior end, with well-marked funnel-shaped collar; duct long, much contorted, and confined to XII. Spermathecæ each with pear-shaped ampulla which connects with digestive tract and bears a circle of seven diverticula; duct about twice as long as ampulla; ectal end with a few small unicellular glands.

Described from six sexually mature specimens. Type and paratypes in the collection of the writer. Paratypes also in the collection of Professor Frank Smith.

The specimens which are the basis of this description were collected near Oconee, Illinois, November 5, 1910. They occurred rather abundantly under the decaying bark of fallen timber. Of the total number of specimens collected at that time about one-half were sexually mature.

Affinities.—This species belongs to the group having more than two diverticula on a spermatheca. A careful comparison of its characters with the corresponding ones of the other species of the genus shows that it is a distinct form. It is difficult to compare it with some of the foreign species, since their descriptions are too brief to enable one to determine the relationship with any degree of accuracy. However, no foreign species appears to be closely related to this form. As regards the American species there is only one of them which might be regarded as a near relative, namely, *Fridericia tenera* Smith and Welch; and disregarding their minor differences, the characters of the brain and the peptonephridia are sufficient to separate them specifically.

EXTERNAL CHARACTERS

The body is slender and has a length of 13–17 mm. In transverse section it is circular and has in the region of the clitellum a maximum diameter of 0.34–0.43 mm. In living specimens the body appears opaque and whitish. The prostomium is blunt, rounded, and rather short. The intersegmental grooves, excepting the first three or four, are very obscure. The number of somites is variable, the extremes being 44 and 60. The clitellum is well developed and occupies XII–XIII. The setæ bundles usually contain 4–6 setæ. Sometimes the number is as high as 8, but this happens rarely. In the last four or five somites the number varies from 1–4. The setæ are simple and straight except for the distinct bend at the proximal end. They are of different lengths in a bundle, the outer ones being longest and stoutest. The head pore is small and on 0/I. In one of the preparations the lymphocytes, which are abundant in the anterior part of the body, were passing out through this opening at the time of fixation. This seems corroborative of the statement of Cuénot ('97, p. 90) that the cœlomic fluids are often exuded through the "dorsal pores" when the animal comes in contact with some irritating substance, and it is possible that in this instance the chloretone was the irritating substance.

The cuticula is thick, firm, and approximately uniform in thickness throughout the length of the body. In the first few somites the hypodermis is about 2–2½ times thicker than the cuticula, but throughout the greater part of the body the latter has about the same thickness as the former, being sometimes even slightly thicker. The presence of the thick cuticula in these specimens evidently supports the statement of Vejdovský ('79, p. 11) that species living in comparatively dry localities are characterized by a thick cuticula. The specimens of *oconeensis* were found under the decaying bark of fallen timber, and while the decaying wood in which they lived was somewhat damp, yet the percentage of moisture was low.

INTERNAL CHARACTERS

Brain.—This organ (Pl. X, Fig. 35) occupies a median dorsal position in I and II, being chiefly in the latter. Both anterior and posterior margins are convex; the lateral margins converge cephalad. The average of a number of measurements shows that it is about twice as long as wide. These two dimensions differ somewhat in different specimens, but the ratio is nearly uniform. A fairly rep-

resentative brain measured as follows: length, 0.153 mm., width, 0.085 mm. A distinct neurilemma encloses the organ and is slightly thickened on the posterior margin. Two pairs of strands attach the organ to the body wall, one arising near the mid-lateral part and the other from a latero-posterior position. In transverse section the brain is almost circular.

Peptonephridia.—Two of these organs (Pl. XI, Fig. 39) lie ventrad to the digestive tract, one on either side of the median line. Each opens independently into the œsophagus in a latero-ventral position in the posterior part of IV. There is some variation in length. In some specimens they extend into VII and in others only to VI. The general structure is, however, the same. They lie parallel to the digestive tract, and both gradually diminish in diameter towards the terminus. They are roughly tuberculate in appearance and give off short single tubular branches at irregular intervals. The branching is much more marked at the posterior end, although even there it is sparse. Anteriorly the branches are given off only at wide intervals, are short, and show no secondary branching.

Chylus Cells.—Chylus cells occur in the wall of the intestine in ½XIV–XVIII. As in certain other species of *Fridericia* previously described, the epithelial layer of the intestinal wall in this region (Pl. XI, Figs. 38, 41) is composed of two distinct kinds of cells, the ental epithelial cells, which line the lumen of the intestine, and the chylus cells, which lie deeper in the intestinal wall and meet the lumen only at points between the ental epithelial cells. The ental epithelial cells are wedge-shaped, the larger ends being entad. In sections the smaller ends appear to be inserted between the apices of the chylus cells either singly or in groups of two, usually the latter. Each ental epithelial cell contains a large elliptical nucleus in the ental end, and the surface bordering on the intestinal lumen has numerous long cilia. The ectal end is in contact with the perivisceral blood sinus. Each chylus cell is flask-shaped, the broader end being ectad, and is about three times as long as broad. The base is long and slightly truncate, the apex rather pointed, exposing little surface to the lumen of the intestine, and the sides of the cell converge gradually entad. The intracellular canal extends the full length of the cell. Its apical half is straight or nearly so, but the basal part often shows two distinct spiral turns. The lining of this canal appears to be little more than a mere bounding membrane. Only the apical half of the canal is ciliated. The relation to the perivisceral blood sinus is intimate. As shown in figures 38 and 41 the surface of the base and from one half to two thirds the length of the sides are in contact with the sinus. A distinct

spherical nucleus lies in the base of each cell, usually in one of the broader angles made by the curves of the intracellular canal. Interstitial cells are absent.

The characters of the chylus cells are uniform, and tend to confirm Eisen's conclusion that they have taxonomic value. A comparison with other species in which the chylus cells have been worked out shows that in none of them do these cells resemble closely those of *oconeensis.*

Nephridia.—The nephridia are rather large and conspicuous. The anteseptal part (Pl. X, Fig. 36) is approximately as large as the postseptal part. The first pair appears on VI/VII. The efferent duct arises from the postseptal part a short distance from the septum and opens exteriorly just anterior to the ventral setæ bundles. The lumen is very tortuous throughout its entire length.

Spermiducal Funnel.—The spermiducal funnel (Pl. XI, Fig. 40) is cylindrical. The posterior end diminishes uniformly to the diameter of the sperm duct which arises from it. The anterior end is characterized by a well-developed protruding funnel-shaped collar, distinctly set off by a transverse constriction. The length of the funnel is about twice its diameter. It lies in the usual position, with the anterior end pointing dorso-cephalad owing to the distinct bend in the body of the funnel. The lumen is eccentric as shown in transverse section, being nearest the ectal surface of the organ.

Penial Bulb.—The structure of the penial bulb (Pl. XI, Fig. 42) conforms to the lumbricillid type as defined by Eisen. It is composed of cells of one kind only. Each cell has two parts; the main body, which lies near the periphery of the bulb and contains a large oval nucleus, and the prolongation, which reaches to the penial lumen. The body of each cell has a strong affinity for stains, while the prolongation stains only very slightly. The sperm duct unites with the bulb on the dorso-ectal surface, where it meets the penial lumen. The bulb is covered by a well-developed musculature. The general structure of this organ is the same as in *Fridericia tenera* Smith and Welch, but when the two bulbs are carefully compared, distinct differences appear in shape, in the mode of union of the sperm duct with the bulb, in the musculature, and in the character of the component cells.

Spermathecæ.—Each spermatheca (Pl. X, Fig. 37) has three well-differentiated parts; the duct, the ampulla, and the diverticula. The duct opens laterad in IV/V. Two or three inconspicuous unicellular glands occur at this opening, but they are so small that high magnification is required to distinguish them. The duct is approximately uniform in diameter throughout its length and is usually more than twice

as long as the ampulla. Measurements of this duct in a number of specimens show the length to be about 13–15 microns. The pear-shaped ampulla unites with the digestive tract well down on the side of the latter in the posterior part of V, thus bringing the openings of the spermathecæ almost directly opposite each other. The ampulla is 6–7 microns long; has a conspicuous lumen; and bears seven globular diverticula, which are arranged in a single whorl. The diverticula differ somewhat in size, but the structural plan is the same in all, and the lumen of each is continuous with the lumen of the ampulla. An examination of a number of sexually immature specimens showed that the spermathecæ are the last of the reproductive organs to attain their complete development. Some of the specimens, with all of the other reproductive organs well developed, had small spermathecæ, with the ducts and ampullæ well developed but lacking the diverticula, the only indication of their future position being the rounded collar-like shoulder on the ectal end of each ampulla. A later stage in the development was noted in which the above-mentioned shoulder of the ampulla had begun to show slight divisions and the boundaries of the diverticula were becoming distinct. Intermediate stages showing the transition between the above-described stages were also found. While no material was available for a study of very early stages in the development of the spermathecæ, it is quite probable that the following order of development obtains: (1) the development of the duct, (2) the development of the ampulla, and (3) the development of the diverticula.

FRIDERICIA SIMA n. sp.

(Pl. XI, Figs. 43–49; Pl. XII, Figs. 50, 51)

Definition.—Length, 15–19 mm. Diameter, 0.45–0.57 mm. Somites, 52–58. Color, whitish with slight tinge of yellow. Prostomium prominent and pointed. Dorsal pores begin on VII. Setæ of the typical *Fridericia* type; 4–6 (rarely 7 or 8) setæ per bundle in the anterior region; 4 (rarely 5) per bundle in middle region; and 2–3 per bundle in the posterior region. Clitellum on XII–⅔XIII. Brain about twice as long as wide; posterior margin moderately convex, anterior margin very convex and slightly pointed at extremity, lateral margins almost parallel. Peptonephridia simple, unbranched, and confined to V. Dorsal vessel arises in XX. Nephridia with well-developed anteseptal and postseptal parts, the latter being longer and slightly larger than the former. The efferent duct arises from the ventral side of the postseptal part about midway of its length; small distinct reservoir present at its ectal opening. Spermiducal funnel

cylindrical, about twice as long as its greatest diameter, with distinct protruding collar. Spermathecæ with duct and ampulla distinctly differentiated; ampulla simple, thin-walled, pear-shaped, and devoid of diverticula; junction with the digestive tract on the dorsal surface of latter but distinct from corresponding junction of opposite spermatheca; duct about twice as long as ampulla, with no glands at ectal opening.

Described from ten sexually mature specimens. Type and paratypes in the collection of the writer, and paratypes in the collection of Professor Frank Smith.

The specimens which are the basis of this description were collected near Urbana, Illinois, April 1, 1911. They were all in a very restricted locality in undisturbed forest-land, under the decaying leaves, and at a slight depth in the rich moderately moist humus. The majority of the specimens collected were sexually mature.

Affinities.—The structure of the spermathecæ puts this form into the group of species having no diverticula on the ampulla. There are at present but six representatives of this group in North America, the majority of them being found in Europe. This worm evidently has no close relatives among the foreign forms since the differences existing between them are numerous and well marked. Of the six American species, only two, *F. alba* Moore and *F. parva* Moore (=*F. bulbosa* Rosa?), appear to be at all closely allied to *F. sima,* and both of these show several distinct differences from the new species.

EXTERNAL CHARACTERS

The body is slender, cylindrical, and tapers from XII or XIII gradually towards the two extremities. The length varies from 15 to 19 mm. The diameter is greatest in the region of the clitellum and varies from 0.45 to 0.57 mm. The color of the living worm is whitish with a slight tinge of yellow. The intersegmental grooves are obsolete in all parts of the body except in the extreme anterior region, where the first of these grooves and sometimes the second and third grooves are well marked. The somites vary from 52 to 58. The clitellum is on XII–⅔XIII and is well developed. The prostomium (Pl. XI, Fig. 47) is prominent and pointed. It varies slightly in shape, but the typical form is that indicated in the figure. In one or two of the specimens examined the prostomium was shorter and more rounded, but it is possible that this difference was due to a contraction of the specimens. The setæ are of the typical *Fridericia* type. They are well developed, and the greater part of their length pro-

jects beyond the body wall. In the anterior region there are 4–6 (rarely 7 or 8) setæ per bundle; in the middle region, 4 setæ (rarely 5) per bundle; and in the posterior region, 2–3 setæ per bundle.

INTERNAL CHARACTERS

Brain.—The brain (Pl. XI, Fig. 48) lies in the dorsal part of I and II, chiefly in the latter. It is about twice as long as wide. The posterior margin is broadly convex, while the anterior margin is strongly so. The lateral margins are approximately straight and almost parallel, diverging only slightly caudad. In transverse section the brain is elliptical in outline, its long diameter being approximately twice as long as its shorter one. Two pairs of supporting strands arise from its posterior part and extend obliquely across the cœlom to unite with the body wall.

Peptonephridia.—The peptonephridia (Pl. XI, Fig. 43) are simple and unbranched. They arise from the digestive tract in the anterior part of V and extend caudad approximately parallel to it, ending in the posterior limit of V. The openings into the digestive tract are latero-ventrad. Both peptonephridia are practically of the same length and the free ends are usually closely approximated. In shape these organs are cylindrical, sometimes slightly flattened. The maximum diameter is just caudad of the point of union with the digestive tract, and from there the organs taper gradually to their free extremities. Slight irregularities on the surface produce a tuberculate appearance, which, however, is not strikingly distinct. Sections show these organs to be tubular, and conspicuous nuclei appear in the walls.

Chylus Cells.—Chylus cells (Pl. XI, Fig. 46) occur in the wall of the intestine in a region including the caudal third of XIV and extending to the anterior part of XVII. In longitudinal sections this region is very easily located by the abrupt increase in the thickness of the intestinal walls. The cells are rather closely crowded, forming an almost continuous layer. They are flask-shaped, somewhat truncate at the ectal end, and the sides converge slightly entad. The intracellular canal is distinct and its apical course is straight, but the basal portion is bent at almost a right angle and is sometimes slightly sinuous. The lining of the canal appears to be a very thin cytoplasmic layer, but in many of the preparations it is rather difficult to distinguish it. Cilia are present for almost the entire length of the canal. The perivisceral blood sinus is quite large in this region, transverse sections of the worm showing it to be in contact with the greater part of the surface of the cells. The ental epithelial cells are more or less block-shaped, distinctly nucleated, heavily ciliated on

the ental surface, and form a layer of which the continuity is broken only by the apical parts of the chylus cells. No interstitial cells are present.

Nephridia.—The nephridia appear first on VI/VII. The anteseptal part (Pl. XI, Figs. 44, 45) is well developed, ovate, and provided with a distinct ciliated nephrostome. The postseptal part is longer and slightly larger than the anteseptal part. There appear to be two divisions in the former; an anterior smaller one and a posterior larger one. The smaller region is a kind of neck by which the posterior large one is joined to the anteseptal part. The origin of the efferent duct presents an interesting feature. It becomes distinct from the ventral surface of the postseptal part at about the middle of its length. A critical examination of the nephridia in the various parts of the body and in the various specimens reveals two rather distinct features which seem to throw light upon the true origin of the duct. A number of nephridia were studied in which it was evident that the posterior end of the nephridium was reflected ventrad upon itself (Pl. XI, Fig. 44) for some distance and then diverged as the duct proper, thus pointing to the fact that the duct really arises from the posterior end of the postseptal part. It should be noted that this reflected portion meets and attaches itself to the ventral side of the nephridium proper, the line of union appearing in sections only as a single line of fusion. Quite a number of nephridia were found (Pl. XI, Fig. 45) in which the above-described condition of the caudal end of the postseptal part was not shown, the duct arising from the ventral surface of the postseptal part about midway of its length. This variation may be interpreted by regarding the first condition as the transitional stage and the second one as the resulting one. Another interesting observation is connected with the efferent duct, a small but distinct reservoir being present at its ectal extremity. Just before the lumen of the duct reaches the exterior it expands into a more or less flask-shaped reservoir which in turn opens to the exterior through a small pore. The lumen of the nephridium is much longer and more contorted in the postseptal than in the anteseptal part.

Spermiducal Funnel.—The spermiducal funnel (Pl. XI, Fig. 49) is cylindrical, usually slightly bent, and approximately twice as long as the greatest diameter. There is a distinct collar set off from the body of the funnel by a constriction. This collar is not reflected, but is funnel-shaped.

Penial Bulb.—The penial bulb (Pl. XII, Fig. 51) is of the lumbricillid type. It is rather simple in its structure and moderate in

size. In transverse section it appears as an elliptical structure with the long diameter approximately parallel to the penial invagination. The greater part of the ental surface of the organ is covered with a well-developed musculature which is a continuation of the circular muscle layer of the body wall. The body of the bulb is composed of cells of one kind, which have their enlarged nucleated parts near the periphery and each of which sends a long process in an ectal direction. These prolongations lie parallel to each other, and the majority of them end radially around the penial lumen. Others end on the ectal surface ventrad to the penial pore. The sperm duct unites with the bulb on the ectal surface. In the retracted state the penial lumen shows a very decisive bend of about 120 degrees before it opens into the invagination. None of the specimens examined showed the bulb in the everted condition. Many of the preparations showed a break or cleft in the body of the bulb which conformed in direction to the long diameter and, in a single section, appeared to separate the nucleated ends of the cells from the greater part of the cell prolongations.

Spermathecæ.—Each spermatheca (Pl. XII, Fig. 50) consists of two clearly differentiated parts, the ampulla and the duct. The ampulla is simple, pear-shaped, and has no diverticula. Its inner end is united with the latero-dorsal part of the digestive tract in the posterior part of V. The cavity of the ampulla conforms in general to the shape of the exterior. The walls are rather thin except at the ectal end, where they are conspicuously thicker. The duct extends, with very few curves, to its external opening in the anterior part of V. There are no glands at the ectal opening. The duct is about twice as long as the ampulla. The external hypodermis surrounding the external opening of the duct is distinctly thickened.

ENCHYTRÆUS Henle

The genus *Enchytræus* was established by Henle in 1837, and although the limits of the group have been altered from time to time it appears to have a permanent place in the family. Michaelsen ('00, p. 88) defines the genus as follows: "Borsten in 4 Bündeln, 2 ventralen und 2 lateralen, gerade, die eines Bündels gleich lang. Kopfporus klein, dorsal zwischen Kopflappen und 1. Segm.; Rückenporen fehlen. Ursprung des Rückengefässes postclitellial; Blut meist farblos; Herzkörper fehlt. Lymphkörper von einerlei Gestalt. Peptonephridien vorhanden oder fehlend; der Oesophagus geht allmählich in den Mitteldarm über. Ausführungsgang der Nephridien

am hinteren Pol des Postseptale entspringend, meist sehr kurz. Samenleiter lang. Samentaschen mit dem Darm kommunizierend, ohne Divertikel."

In the light of recent work this definition is faulty. The statement that the spermathecæ communicate with the digestive tract does not always hold, since in *E. modestus* Eisen there is no such connection; and the statement that the spermathecæ have no diverticula can not now stand, since species have been described (*E. alaskæ* Eisen, *E. saxicola* Eisen, and *E. citrinus* Eisen) in which there are diverticula on the ampulla.

Eisen ('05, p. 61) modified the definition of the genus as follows: "Setæ of equal length and straight. Head-pore between prostomium and somite I, always small. No dorsal pores anterior to clitellum. Intestine and œsophagus gradually merging into each other. Dorsal vessel rises posterior to clitellum from a vascular sinus of the intestine. One pair of sperm-sacs, surrounded by peritoneal membrane, project from the testes forward. No single penial bulb, but one or more isolated glandular papillæ situated in the vicinity of the spermiducal pores, generally and principally ventral to the pores. Numerous transverse muscles connect the ventral and lateral parietes surrounding the spermiducal pores. Peptonephridia glands present or absent. One kind of lymphocytes. Intestine generally with chylus cells."

It will be noted that in Eisen's definition statements concerning the sperm sacs and the structure of the penial bulb have been added. It is doubtful if either of the two points made can be considered as constant features of the genus. In *E. gillettensis* n. sp. and *E. indicus* Stephenson sperm sacs are absent, and in certain species recently described (*E. nodosus* Stephenson, *E. dubius* Stephenson, and others) no mention is made of them. Furthermore, *E. gillettensis* has a single compact penial bulb not broken up into isolated papillæ, and *E. nodosus* is similar in this respect. It thus appears that the structure of the penial bulb in this genus as described by Eisen is not a constant character.

About thirty-two species have been assigned to this genus, and of this number eight have been recorded from North America and its adjacent islands. Seven of the eight species were originally described from this continent. The list and type localities are as follows: *E. modestus* Eisen (Orca, Prince William Sound, Alaska), *E. metlakatlensis* Eisen (Metlakatla, Alaska), *E. kincaidi* Eisen (Popof Island, Alaska), *E. alaskæ* Eisen (Garforth Island, Muir Inlet, Glacier

Bay, Alaska), *E. saxicola* Eisen and *E. citrinus* Eisen (Lowe Inlet, British Columbia), *E. marinus* Moore (Bermuda Islands), and *E. albidus* Henle (Germany; N. American locality, Massachusetts, U. S. A.). One new species, *E. gillettensis,* is described in the following pages.

Key to the Species of Enchytræus known to occur in North America

1 (10) Diverticula present on ampulla of spermatheca.
2 (7) One diverticulum on ampulla of spermatheca.
3 (6) Spermiducal funnel with length not exceeding four times the diameter.
4 (5) Peptonephridia present; brain with convex posterior margin; length, 20–25 mm. .... *kincaidi*
5 (4) Peptonephridia absent; posterior margin of brain with slight median concavity; length, about 10 mm........... *marinus*
6 (3) Spermiducal funnel very long and narrow, length exceeding four times the diameter; posterior margin of brain with deep emargination; extensive sperm sacs present; length, 15–20 mm. .... *saxicola*
7 (2) Two diverticula on ampulla of spermatheca.
8 (9) Posterior margin of brain concave; diverticula of spermatheca equal in size..................................... *alaskæ*
9 (8) Posterior margin of brain convex; diverticula of spermatheca unequal in size.................................. *citrinus*
10 (1) No diverticula on ampulla of spermatheca.
11 (12) Spermatheca not connecting with digestive tract, straight and more or less covered throughout its entire length with small glandular cells; no distinct and enlarged ampulla. . *modestus*
12 (11) Spermatheca connected with digestive tract.
13 (16) Spermatheca short and stout, the duct being about the same length as ampulla; length exceeding 10 mm.; somites over 50.
14 (15) Duct of spermatheca not set off distinctly from ampulla; connects with digestive tract at one side of ampulla and not at apex; large compact crown of glands at ectal opening..... .... *metlakatlensis*
15 (14) Duct of spermatheca distinctly set off from ampulla; connection with digestive tract apical; ectal half of duct covered with closely set pear-shaped gland cells.................. *albidus*
16 (13) Spermatheca long and slender, the duct being about four times as long as ampulla; glands cover entire length of duct; length, 2.5–4.5 mm.; somites, 25–27 .... *gillettensis*

ENCHYTRÆUS GILLETTENSIS n. sp.

(Pl. XII, Figs. 52–56)

Definition.—Length, 2.5–4.5 mm. Diameter, 0.144–0.188 mm. Somites, 25–27. Color, whitish. Prostomium blunt and rounded. Lymphocytes few in number, ovoid, nucleated. Setæ straight, those of a bundle of equal size; number per bundle, 2–3, rarely 4 or 5. Clitellum on XII–XIII. Brain about twice as long as broad; anterior margin concave; posterior margin almost straight; lateral margins converging cephalad. Peptonephridia present, arising from dorsal surface of pharynx in III as two separate organs; slightly branched; usually terminating in a large mass. Dorsal vessel arises in XIV. Anteseptal part of nephridia small and inconspicuous, comprising little more than the nephrostome; postseptal part large; short efferent duct arises from posterior end of postseptal part. Length of spermiducal funnel 3 to 4 times the greatest diameter; collar distinct; distinct bend in middle of funnel. Duct of spermatheca about four times the length of ampulla and completely covered with small glands; ampulla spherical, thin-walled, destitute of diverticula, and connected with digestive tract.

Described from fifteen specimens, all of which are sexually mature. Type and paratypes in the collection of the writer. Paratypes also in the collection of Professor Frank Smith.

The specimens which form the basis of this description were collected by Dr. George R. LaRue at Gillette Grove, Iowa, in August, 1910. They were found in damp black soil, under the drip of a building.

Affinities.—Nothing definite can be accomplished in attempting to establish the relationships of this species owing to the incomplete and ambiguous descriptions of some of the European species. All that can be done at present is to call attention to the apparent similarity which exists between this form and some of the other species as judged by those characters which are described in sufficient detail to be used in diagnosis, keeping in mind meanwhile the possibility that future investigation may show that they are not at all closely related. This species approaches *E. argenteus* Mchlsn. closely in some respects, but shows differences in the characters of the nephridia, the spermiducal funnel, and the spermathecæ. In other particulars it resembles *E. sabulosus* Southern, but distinct differences exist in size, number of somites, the brain, and one or two other organs. It also resembles *E. indicus* Steph. but differences exist in the peptonephridia and the spermathecæ. Of the American species it most nearly approaches *E.*

albidus Henle; but here distinct differences occur in length, number of somites, and spermathecæ.

EXTERNAL CHARACTERS

Twenty-seven alcoholic specimens have a length varying from 2.5 to 4.5 mm. They had been carefully killed and fixed, and since microscopical examination of the whole series showed no conspicuous contraction it is safe to consider these measurements as fairly accurate. The number of somites is rather constant, varying within the limits of 25 and 27. The greatest diameter, which is in the region of the clitellum, is 0.144–0.188 mm. The body is smooth, cylindrical, and tapers very gradually caudad from the clitellum. The clitellum is only moderately developed and occurs on XII and XIII. It is interrupted on the mid-ventral surface. The intersegmental grooves are most distinct in the anterior region; posteriorly they tend to become obsolete. The prostomium is blunt and rounded. The setæ are sufficiently described in the definition.

INTERNAL CHARACTERS

Lymphocytes.—The lymphocytes are scattered throughout the greater part of the cœlom, but occur only in small numbers. They are nucleated, ovoid, and have a decided affinity for stains.

Chloragog Cells.—The elongated club-shaped chloragog cells are very highly developed. They first appear in V, and from that point caudad they almost completely cover the digestive tract, filling the greater part of the cœlom. The cytoplasmic contents are distinctly reticular and sometimes appear to be alveolar in structure.

Brain.—The brain (Pl. XII, Fig. 52) lies chiefly in I and II. The length varies slightly in the different specimens, but the ratio of the length to the greatest diameter appears to be almost uniformly 11 : 6. The posterior margin is approximately straight, although in some specimens there is a slight convexity. The lateral margins converge anteriorly, the smallest width being just posterior to the origin of the commissural trunks. The anterior margin is concave and slightly V-shaped. A neurilemma surrounds the brain and appears to be thickest about the posterior margin. Two pairs of strands connect the brain with the body wall, one pair arising from the lateral margins near the region of the greatest diameter, the other arising near the region of junction of the lateral margins with the posterior one. In transverse section the brain is ovoid in shape. Close examination of cleared specimens showed the presence of an elliptical area in the re-

gion of the greatest width. Eisen ('05, p. 62) calls attention to this area as follows: "The brain in *Enchytræus* is characterized by the circular mass of fibers in the posterior part of the fiber belt in the brain. As this structure has not been studied in detail its nature is not understood." Dr. Eisen evidently regarded this structure as more or less characteristic of the genus, although he makes no mention of it in the description of the brain in his *alaskæ* and *citrinus,* and his figures of these species do not show any indication of its presence. The writer has nothing to contribute to our knowledge of this area, but it is certainly present in *E. gillettensis.*

Peptonephridia.—These organs are very conspicuous in the anterior region of the body. They are similar and arise, one on either side, from the dorsal surface of the pharynx immediately posterior to its dorsal epithelial thickening in III. They extend caudad for about the length of one somite. Each shows irregular branches, and makes irregular contortions in the cœlom on either side of the digestive tract. These organs terminate in a peculiar manner. In some specimens both peptonephridia merge into a large mass dorsad of the digestive tract; in other specimens only one organ ends in this mass; and in one preparation this mass is absent.

Nephridia.—These organs (Pl. XII, Fig. 54) are large and appear as conspicuous masses on the floor of the cœlom. The anteseptal part is small and inconspicuous, being little more than a nephrostome. The postseptal part is large, ovoid, and comprises the bulk of the organ. The nephridia appear to differ slightly in shape in the various regions of the body, the anterior ones being somewhat shorter and thicker than those posterior to the clitellum. The short efferent duct arises from the posterior surface of the postseptal part, bends abruptly ventrad, and opens to the exterior slightly ventrad to the posterior end of this part.

Spermiducal Funnel.—The spermiducal funnel (Pl. XII, Fig. 55) is cylindrical, rather small, and 3 to 4 times as long as broad. The collar is well developed and is set off by a distinct constriction. The funnel usually shows a marked bend in the middle, the convex aspect being dorsad. The maximum diameter is just back of the collar. From this point it gradually diminishes, the funnel merging into the sperm duct without any abrupt decrease of diameter.

Penial Bulb.—The penial bulb (Pl. XII, Fig. 56) is compact, globular, and enclosed in a simple muscular investment. It is composed of cells of a single kind which all appear to empty at the body surface. Large spherical nuclei lie in the ental ends of the cells, showing in transverse section as a continuous row around the periphery of

the bulb. A few nuclei appear in the vicinity of the sperm duct. This duct penetrates the bulb on its ectal side, and after making a bold curve within the bulb opens into the shallow invagination. The bulb is covered by a thin sheet of peritoneal membrane beneath which lies a thin layer of muscle tissue. This musculature does not penetrate the bulb, nor is the bulb divided into separate parts as seems to be the case in some species of this genus.

Spermathecæ.—Two moderately developed spermathecæ are present in V. Each spermatheca (Pl. XII, Fig. 53) is distinctly differentiated into two regions, the duct and the ampulla. The duct is about four times longer than the ampulla, and is covered throughout its entire length with small glands which give it a tuberculate appearance. The lumen is very fine and the walls of the duct are thick. There seem to be a few additional unicellular glands at the ectal opening, but they are small and not easily seen. The ectal opening is somewhat latero-ventral in position and occurs near IV/V. From this point the duct extends, without contortions, in a dorso-meso-caudal direction. Before reaching the digestive tract it merges into the ampulla. The ampulla is spherical, thin-walled, and unites with the lateral surface of the digestive tract by means of a short duct-like extension. All of the specimens studied showed masses of sperm cells in the globular ampulla.

The Penial Bulb as a Character in Classification

Previous to 1905 the structure of the penial bulb had not been critically examined and no attempt had been made to discover in it characters of taxonomic importance. It had been seen and very briefly described by some of the earlier workers (Vejdovský, Michaelsen, *et al*), but the finer details of structure were neglected. As a consequence scarcely any of the earlier publications on *Enchytræidæ* give information, either in text or figures, which can be used in estimating the taxonomic value of this organ. Eisen ('05) made critical studies of it in about fifty species, distributed among eight genera, and gave descriptions and figures of the structure of the organ in each case. Unfortunately these species were not evenly distributed among the eight genera, since in two of them but one species each was examined, and in another only two species. The most thoroughgoing examination was made in the genus *Mesenchytræus,* in which twenty species were studied. The results of this extended study are given by Eisen ('05, p. 6) as follows:

"The present arrangement of the various genera is partly tentative. Until now the structure of the penial bulb has not been critic-

ally examined, except in a few species besides those described in this paper, and it is in reality only a supposition that the structure of the penial bulb is uniform in the respective species of a genus. I think, however, this assumption will prove to be correct. The species within each of the genera which have been examined have proved to correspond in all particulars to such an extent that it may be safely assumed that the other species will also agree.......The copulatory cushion or penial bulb is of considerable importance in the classification of *Enchytræidæ,* and I have, as far as it has been possible, investigated its structure in all of the species described in this paper.......it seems almost certain that a great uniformity of structure exists in the different species of the same genus, or in the same genera of the various subfamilies. The structure of the penial bulb or corresponding organs can therefore be said to be highly characteristic of both species, genera and subfamilies."

According to Eisen there are three distinct kinds of bulbs, the mesenchytræid bulb, the enchytræid bulb, and the lumbricillid bulb, which he defines as follows ('05, p. 7):—

"The Mesenchytræid bulb is a single muscular structure, containing circular muscles as well as fan-shaped muscular bands connecting the body wall with the periphery of the bulb. Between the muscular bands are generally found numerous penial glands which open on the surface of the bulb around the penial pore. The sperm-duct penetrates the bulb, opening on the center of its outer surface.

"The Enchytræid bulb is multiple, consisting of several separate cushions grouped around the penial pore. In these cushions we find several sets or fascicles of glands, each fascicle opening by itself on the surface of the body. There are no muscular bands connecting the base of the cushions with its periphery. The sperm-duct never penetrates the bulbs or cushions but opens close to and independently of them. Exterior to the cushions there are numerous muscles connecting the body wall immediately surrounding the pore with other parts of the same somite.

"The Lumbricillid bulb is always single and covered with a strong muscular layer, which however never penetrates down between the cells of the bulb. There are generally two or three distinct sets of glandular cells in the bulb. Some of these open in the lower part of the sperm-duct, or rather in a narrow groove in the elongation of the sperm-duct. Others open on the free surface of the bulb, either irregularly or in narrow circular fields, bunched into fascicles. The sperm-duct penetrates one side of the bulb. In *Bryodrilus* the gland which opens in the extension of the sperm-duct is covered with a thin cushion of muscular strands, forming a bulb within a bulb."

Eisen distributed the eight genera he examined in this connection as follows: having the mesenchytræid type of bulb—*Mesenchytræus;* having the enchytræid type of bulb—*Enchytræus* and *Michaelsena;* and having the lumbricillid type of bulb—*Lumbricillus, Marionina, Bryodrilus, Henlea,* and *Fridericia.*

Eisen was convinced that the structure of the penial bulb is of "great taxonomic importance" and he used it as the chief character in distinguishing subfamilies, added it to the definitions of the genera, and gave it a prominent place in his descriptions of new species.

The family *Enchytræidæ* now contains sixteen genera and nearly three hundred species. Since Eisen's investigation was based on about fifty species distributed among eight genera it is evident that his work must be extended and his conclusions tested on other species and genera before the structure of the penial bulb can be considered as a safe diagnostic character. Considerable work has been done on foreign *Enchytræidæ* since 1905, but it has been in the form of numerous small papers, no comprehensive works having appeared. As a consequence the systematic value of the penial bulb has been but little discussed. Stephenson ('11, p. 54) is inclined to discredit the use of the penial bulb "as a basis for the distinction of subfamilies or, even, perhaps, of genera." Most other foreign workers have been noncommittal on the subject.

There is no doubt that the discovery of taxonomic characters in the structure of a rather conspicuous internal organ such as the penial bulb is a step in advance, and the desirability of adding to the somewhat limited list of specific and generic characters in *Enchytræidæ* is obvious to any one who has worked in the group. The writer has given special attention to the structure of this organ in all of his work, and critical studies have been made on all of the species and genera available, not only with the view of determining the minute structure of this interesting organ, but also to test the validity of Eisen's conclusions as to its systematic significance, hoping to add something new, if possible, to the data already accumulated.

Some interesting results have been obtained. In some cases they lend support to Eisen's conclusions; in others it is apparent that certain limitations and alterations must be made in Eisen's system; and in still others it is clear that certain generic differences given by Eisen do not hold. Owing to the importance of this subject the results of the present study will be discussed in some detail. The studies of the writer on the penial bulb have been made on fourteen species distributed among five genera, namely, *Henlea* (*urbanensis* and *moderata* n. spp.), *Marionina* (*forbesæ* Smith and Welch), *Lumbricillus* (*rutilus* n. sp. and *insularis* Ude), *Enchytræus* (*gillettensis* n. sp. and

albidus Henle), and *Fridericia* (*agilis* Smith, *tenera* and *firma* Smith and Welch, *agricola* Moore, and *sima, oconeensis,* and *douglasensis* n. spp.).

For convenience these genera will be considered separately, and in the order named.

Henlea urbanensis and *H. moderata* have penial bulbs of the lumbricillid type as defined by Eisen (see p. 174), and exhibit no peculiarity of structure calling for alteration in his conclusions.

Eisen makes the following statement ('05, p. 90) concerning the character of the penial bulb in *Marionina*: "Penial bulb without interior muscular strands.......There are two sets of glandular cells opening in the bulb. One set opens into the lower part of the sperm-duct, while the other opens onto the base around the pore." According to his investigations, both *M. alaskæ* and *M. americana* conform to this description.

Studies on *M. forbesæ* have shown that while the bulb is like Eisen's lumbricillid type in being a single compact structure invested in a musculature which does not penetrate into the interior, it does not have two distinct sets of cells as required by his description of the genus. Instead, the cells are all of one kind and all apparently open on to the surface of the bulb. None could be found which emptied into the sperm duct. Michaelsen ('05b, pl. I) figures the penial bulb of *M. falclandica,* and although it can not be determined whether any of the cells open into the sperm duct, all of the cells in the bulb appear to be of the same kind. The bulb is, however, of the compact lumbricillid type.

Benham ('05, p. 294, pl. XIV, fig. 9) describes and figures the penial bulb of *M. antipodum,* which is a very small organ composed of similar cells through which the sperm duct penetrates. Opening into the dorsal surface is a conspicuous accessory gland which lies entirely outside the bulb and is much larger than the latter. Michaelsen ('05a) described the penial bulb in *M. werthi* as a small organ entirely concealed in the body wall and possessing an accessory (prostate) gland which extends into the body cavity.

Since, then, in both *M. antipodum* and *M. werthi* the penial bulb has an accessory gland, it becomes necessary to modify the definition of the subfamily *Lumbricillinæ* to include this character. Furthermore, it can no longer be said that the bulb in *Marionina* has uniformly two sets of cells within it.

Studies on *Lumbricillus rutilus* and *L. insularis* show that in both species the structure of the penial bulb conforms to the general lumbricillid type as defined by Eisen and calls for no special comment in

this connection. It also appears that the descriptions of penial bulbs which have appeared in the literature since 1905 agree with the definition of the lumbricillid type. Thus far no deviation from this type is known to occur in the genus.

The characteristics of the enchytræid type of penial bulb as described by Eisen have already been given. In defining the subfamily *Enchytræinæ* ('05, p. 61) he makes the following statement concerning the penial bulb: "In this family the penial glandular structures are not confined within a single bulb as in Lumbricillinæ, but are broken up in two or more masses of papillæ, often of unequal size. In a cross-section of the body these papillæ may be seen to extend from the median line to the other side of the spermiducal pore, and even in the long diameter of the body the glands have a more or less considerable extension. In some species these glands are situated close to each other, in others again they are separated by the common tissue of the body-wall." According to Eisen two genera, *Enchytræus* and *Michaelsena,* are characterized by this type of penial bulb. In defining the genus *Enchytræus* Eisen makes the following statement: "No single penial bulb, but one or more isolated glandular papillæ situated in the vicinity of the spermiducal pores, generally and principally ventral to the pores. Numerous transverse muscles connect the ventral and lateral parietes surrounding the spermiducal pores."

The studies made by the writer on the genus *Enchytræus* show that Eisen's diagnosis can not be used safely in distinguishing it. *E. gillettensis* conforms in no respect to the type of penial structure which Eisen claims to be uniform for the genus, but has instead a single compact glandular bulb in which the muscular investment does not penetrate into the interior. No penial structures are present outside of the bulb, and the sperm duct penetrates the bulb. In fact, it is a typical lumbricillid bulb. Stephenson ('11, p. 50, pl. XLVIII, fig. 10) describes and figures the penial structure in *E. nodosus,* which, also, is of the lumbricillid type. It appears that at least two species of the genus are radically different in the structure of the penial bulb from the enchytræid type as defined by Eisen. The writer has also studied the penial structure in sections of *E. albidus,* made from specimens collected at Woods Hole, Massachusetts, by Professor Frank Smith. Michaelsen ('86b, p. 39, pl. II, fig. 3) described and figured the structure of the penial bulb in *E. möbii,* which has been shown to be a synonym of *E. albidus.* The specimens from Massachusetts have penial bulbs which correspond exactly to the description given by Michaelsen. However, the structure of the bulb in *E. albidus* does not conform entirely to the enchytræid type of bulb. It is broken up

into a number of glandular parts or fascicles, but departs from the enchytræid type in having a large central division which is simple, compact, globular, invested in a musculature, and penetrated by the sperm duct,—all of which are characteristics of the lumbricillid bulb.

Stephenson ('11, p. 56) described a new species, *E. dubius,* in which the penial bulb is described as follows: "The penial gland is not large; its peculiarity is that it is bifid internally; thus in a series of longitudinal sections it is first met with as a single mass, while, nearer the middle line, it is completely double. It is attached by two thick strands, composed of cells with large oval nuclei, to the dorso-lateral body-wall." The same writer ('12, p. 240) described another new species, *E. indicus,* in which the penial bulb is a typical lumbricillid bulb. Southern ('09, p. 158) described a new species, *E. lobatus,* in which the character of the bulb is given as follows: "The duct [sperm] ends in a penial bulb, half as large as the funnel."

We may summarize for *Enchytræus* as follows:—

1. It is evident that the limitations laid down by Eisen concerning the variation of the penial bulb in *Enchytræus* do not hold. Future studies may show that the enchytræid form of penial structure is the more common one but it can not be used as a diagnostic character.

2. It appears that there are transitional stages in the structure of the penial bulb in the various species of this genus, ranging from the lumbricillid to the enchytræid type. The bulb in *E. gillettensis* and *E. nodosus* is distinctly lumbricillid; in *E. dubius* there is a partial division of the bulb which is lumbricillid in type; in *E. albidus* one of the several fascicles is lumbricillid in structure; and, finally, in quite a number of species the typical enchytræid type prevails. This may be regarded as additional evidence in support of the contention of Stephenson ('11) that *Enchytræus* and *Lumbricillus* are intimately related, and not widely separated as was formerly supposed.

3. Until the structure of the penial bulb is thoroughly worked out in many of the known species of the genus, any attempt to make necessary modifications in Eisen's classifications must of necessity be tentative. At present the stability of the subfamily *Enchytræinæ* is in question, and future work may necessitate its elimination. There is one bit of evidence which may prove to be of service in the final adjustment of the matter, namely, the absence of penial bulb cells which open directly into the sperm duct. This seems to be the condition in all of the species of *Enchytræus* which the writer has studied, as well as in those worked out by other investigators. However, it seems doubtful if this one feature can be used as a diagnostic character of the genus, since a similar condition appears to exist in certain species of at least one other genus.

Eisen ('05, p. 108) characterizes the penial bulb of *Fridericia* as follows: "The penial bulb of *Fridericia* is quite characteristic and seems to be of similar structure in all of the species investigated by the author. There is only one kind of cells filling the bulb. These cells all open in the extension of the sperm-duct and along the surface of the bulb; the duct connects with the bulb at the base of the latter and cannot strictly be said to enter the bulb." It is necessary to note that Dr. Eisen refers to those cells which open into the penial lumen ("extension of the sperm-duct") and those which open on to the surface of the bulb as *one* kind of cells in his general statement and in the description of several species he refers to them as *different* kinds of cells by stating that the bulb in certain species has two kinds of cells. This lack of precision is due to the fact that while in the bulbs studied by him the cells are all similar, in some cases the cells of a bulb open on two different surfaces, and these were unfortunately referred to as two kinds of cells. However, it is evident from his descriptions and figures that all of the species which he studied had bulbs in which the cells were all of *one* kind.

The work done by the writer shows that although the penial bulb in *Fridericia* is uniformly lumbricillid in all respects, it is necessary to make a slight alteration in Eisen's characterization. It was found that the seven species examined by the writer can be divided into two groups: one group composed of *tenera, sima,* and *oconeensis,* in which the bulb is made up of cells of one kind only, some of which open into the penial lumen and others on the external surface; and the other group composed of *agilis, firma,* and *agricola,* in which the bulbs possess two distinct types of cell, one of which occupies the peripheral parts of the bulb, opening either into the penial lumen or on the external surface, and the other composing the interior of the bulb, the cells arranged radially about the penial lumen and opening directly into it. These two types of cell are quite distinct, showing uniform, marked differences in position, shape, size, size of nuclei, and staining reaction. It appears that the structure of the bulb in *F. douglasensis* represents a transitional stage between the two groups mentioned above, since the inner cells which open into the penial lumen in *agilis, firma,* and *agricola* are represented only by a few scattering cells disposed at irregular intervals between the extensions of the peripheral cells. It is apparent that Eisen's original statement concerning the character of the bulb in *Fridericia* must be so revised that provision is made for the occurrence of two kinds of cells in the penial bulb of certain species; but otherwise his conclusions are supported.

At present little can be positively stated concerning the importance of the penial bulb in separating the species of a genus owing to the incompleteness of the data for the whole group. The writer has found that in each species studied the structure of the bulb is constant, and that in no case is it exactly duplicated in the bulb of another species. In certain genera, as, for example, *Mesenchytræus* and *Enchytræus*, where the penial structure is usually very complicated and the variation rather wide, it is not difficult to find in the structure of the penial apparatus distinguishing characters for species. The main difficulty appears in the lumbricillid bulb, particularly in *Fridericia* in which the structure of this organ is at its simplest, and in which the variation among the species is so small that although the structure of the bulb is uniform for each species, it is difficult to get a distinct diagnostic character.

Observations and Experiments on Lumbricillus rutilus n. sp.

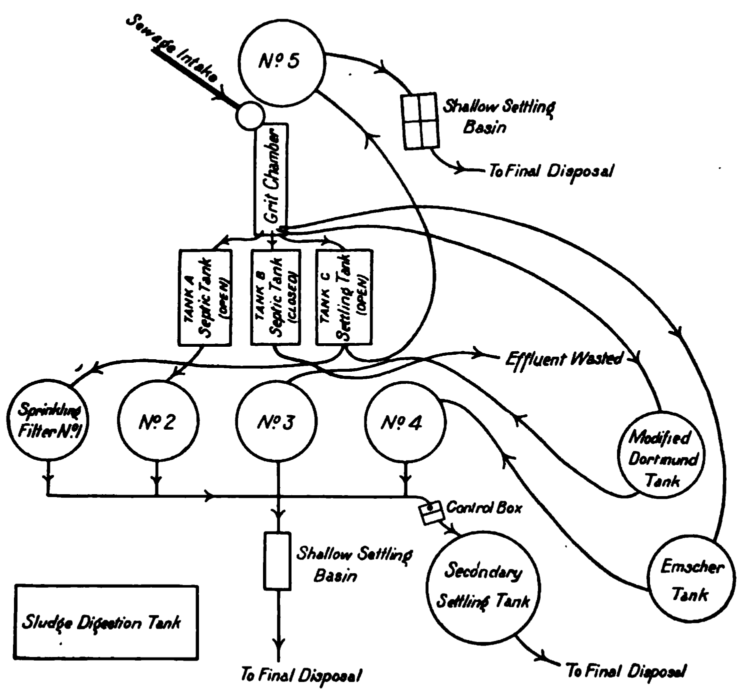
The writer's attention was called to this species in April, 1911, when alcoholic material of the same was turned over to him by Dr. S. A. Forbes, to whom it had been sent by the Director of the Thirty-ninth Street Sewage Testing Station, Chicago, Illinois. The material was accompanied by the information that this worm occurred in great abundance in the sprinkling filter beds. The specimens were in such poor histological condition that an attempt to determine the species was abandoned. Later, June 22, 1911, Mr. A. A. Girault collected similar material at Chicago, made a brief record of the general conditions of the habitat, and had a large number of the specimens properly killed and fixed. This material formed the basis for the morphological and systematic work on this species which has already been included in the paper (pp. 143–151). During October, 1912, the writer spent three weeks at this Testing Station, making certain investigations on this species, and the major part of the data on the living material which follows were accumulated during that period.

HABITAT

Since this is the first published record of an American species of *Lumbricillus* which occurs in connection with sewage, and since its great abundance indicated a particularly favorable environment, the habitat was carefully studied and will be described at some length. Much of the detail which follows is essential to subsequent discussions and explanations of results. It may be noted here that there are records of about six European species which occur normally in

connection with city water supplies, in sewers, near dung heaps, and in various places containing decaying organic matter.

The equipment of the Thirty-ninth Street Sewage Testing Station is as follows: a "grit chamber", 20×4×3 feet, with a capacity of 1,500 gallons at flow depth; three tanks, each 40 feet long, 7 to 9 feet deep and 7½ feet wide, total capacity 19,000 gallons, flow 17,000 gallons, tank "A" being an open septic tank with a nominal eight-hour period, tank "B" a closed septic tank, and tank "C" an open settling tank; an Imhoff or Emscher tank, 7½ feet in diameter and 17 feet deep; a modified Dortmund tank, 7½ feet in diameter and 9 feet deep; five sprinkling filters in cylindrical wooden tanks connected with the settling and septic tanks, four being open and one covered; various settling basins; and a sludge digestion tank 29×7×6 feet, with a total capacity of 8,900 gallons. The following diagram will indicate the relation of these various tanks and filters to each other.



The one important thing to note in connection with the data which is to follow is the nature of the effluents of the various settling and septic tanks. In brief, the aim of modern sewage disposal involves two distinct steps: the disposal of the small amount of suspended mat-

ter as quickly as possible, and the oxidation of the fresh sewage in biologic filters in case additional treatment is demanded.

The first step is accomplished by passing the sewage through the grit chamber, in which the heavier mineral particles are deposited. At the Testing Station, for experimental purposes, the sewage then passes in part to the septic tanks and in part to the settling tank. In the former, anaerobic decomposition of the sewage goes on, eventually resulting in a series of chemical changes which, from the point of view of purity, often render the effluent a great deal worse than the raw sewage entering the tank. The sludge is removed from the settling tanks at frequent intervals while it is still in the early stages of decomposition, the effluent being improved by the process. The principles of the septic and settling tanks are combined in the Emscher or Imhoff tank, which is a device permitting the escape of a "fresh" effluent, while the suspended matter settles, dropping into a separate sludge digestion chamber. The modified Dortmund tank (a kind of settling or biolytic tank) is of such construction that sulphate reduction, due to bacterial activity, is typical, and at times as much as 40 p.p.m. of hydrogen sulphide have been observed in its effluent.

The second step consists in biologic treatment or oxidation of the sewage. This is accomplished in the sprinkling filters, which receive the various effluents from the septic and settling tanks. Since these filters are intimately connected with the work a brief description of them will be given. Sprinkling filters are not built primarily as a device for removing suspended matter, but as a means of oxidizing and mineralizing the organic matter delivered to them. Each sprinkling filter consists essentially of a bed of crushed limestone, 4½ to 10 feet deep, and a central top-surface intermittent spray, which constitutes the influent. The size of the stone, the depth of the bed, and the period of the spray is different in each filter. In sprinkling filter No. 4, the flow-period is about 60 seconds with an intermission of about 30 seconds. The daily flow is approximately 10,000 gallons. Sprinkling filters function to a considerable extent in the catching of suspended matter, and as a consequence sludge accumulates on the stones. The chemical nature of this sludge depends of course upon the character of the influent.

According to the observations of Dr. Lederer and others connected with the testing station, *Lumbricillus rutilus* has a seasonal distribution. The worms apparently disappear completely at the approach of winter (November or early December) but in March or April they begin to appear in all of the sprinkling filters and their effluents. In a short time they become extremely abundant in the

filters, and large numbers are carried out in the effluents. The period of maximum abundance is apparently rather short, but the worms are abundant throughout most of the summer, beginning to diminish in numbers as the autumn wanes. An interesting fact in connection with the period of maximum abundance will be discussed in another connection. No careful observations have as yet been made regarding relative abundance in the different sprinkling filters. Girault (June 22, 1911) found them most abundant in sprinkling filter No. 5, which is covered; but according to the observations of the Sanitary Engineer there is usually at that time of year an abundance in all the sprinkling filters except No. 3.

During the writer's investigations at the Testing Station (Oct. 5–25) a careful examination of all of the tanks, settling basins, and sprinkling filters was made with the view of determining the distribution of the species at that time of year. It was found that the worms were confined to certain of the filters and their effluents. While the greatest abundance occurred in No. 4, a few were found in Nos. 1 and 5, and some in the general filter effluent. Various considerations were found to throw light upon the facts of distribution. Absence of these worms in the septic tanks is, no doubt, due chiefly to the absence of dissolved oxygen and the presence of inimical gaseous decomposition products. Absence in the settling tanks is due probably to the very low dissolved oxygen content. Absence in sprinkling filter No. 2 can be accounted for by the fact that the influent of this tank comes directly from the modified Dortmund tank, where considerable sulphate reduction occurs, its effluent being laden with hydrogen sulphide which is harmful to animal life, not only because it diminishes the available oxygen but because it is itself poisonous. The appearance of the worms in sprinkling filters Nos. 1, 4, and 5 is presumably due to the fact that the influents of these sprinkling filters are effluents of the settling tank and are "fresh." The great abundance in No. 4, as compared with the scarcity in Nos. 1 and 5, in October, seemed to be due to the fact that No. 4 contained an unusual amount of sludge for the time of year, while the quantity of sediment on the stones in Nos. 1 and 5 was decidedly smaller. The reason for the appearance of the worms in the sprinkling filter effluents is a purely mechanical one, since they are carried there by the descending currents of sewage.

The vertical distribution of the worms in the sprinkling filters during the summer is not known; but an examination of No. 4 in October showed them to be largely confined to the upper two feet of the filter bed. Below that limit they occurred but rarely. This verti-

cal distribution of the worms coincided with the vertical distribution of the "load" of the filter, since the greater part of the sludge deposited at this time of year was confined to this zone, while below it the stones were conspicuously cleaner. It seems very probable that it is this feature of the situation which determined the distribution in October, since these worms show a decided affinity for the sludge.

These worms do not appear normally on the upper surface of the filter bed, but may be found by removing the uppermost rock. The physical conditions of this environment are as follows: the light is practically excluded beyond the first six or eight inches; moisture is at a maximum, since large quantities of sewage are constantly flowing down through the interstices; the temperature is cool and in general fairly uniform for a given season; and an abundance of the finer settling suspended matter finds lodgment on the surface of the rock and in the interstices.

The worms are distributed to the different parts of the plant by the streams. They have a specific gravity slightly greater than water and therefore sink slowly when placed in quiet water of some depth; but a stream of water will carry them when they are once loosened from their hold on the supporting rock. The writer has observed instances where several worms had penetrated a mass of sludge which, because of decomposition changes, had acquired a low specific gravity, and when loosened from the point of accumulation, it floated away, easily carrying the additional weight of the worms.

Associated Animal Life.—These lumbricillid worms were not the only animal forms present in the sprinkling filters. In fact, when examined in October, it was found that there were other forms which were more generally distributed and more abundant. No attempt was made to list the microscopic life, and attention was confined to the macroscopic forms, of which the following were the most common: *Prorhynchus* sp., small *Nematoda* (not identified), *Pristina* sp., *Nais* sp., *Helodrilus subrubicundus* Eisen, *Collembola* (*Isotoma* sp.), larvæ and pupæ of *Psychoda albimaculata* Welch and *Chironomidæ,* and water-mites.

COLOR OF LIVING SPECIMENS

To the unaided eye, *Lumbricillus rutilus* presents a general reddish appearance. The region posterior to the clitellum appears uniformly reddish, except that the ventral blood-trunk shows as a deeper red line. The region anterior to the posterior margin of the clitellum is distinctly lighter in color, and the region of X–XII in sexually ma-

ture specimens shows a distinct white spot with no trace of red. The surface layer of the limestone rock composing the sprinkling filter beds acquires after a time a reddish brown color, due partly to the formation of certain ferrous compounds, and with this sort of a background it is often a little difficult to distinguish the worms; but the white spot on X–XII is more or less conspicuous, and soon, if not at once, reveals their presence. When large numbers are placed in water they often accumulate in a compact mass, and in such an aggregation the red color seems to be intensified, the whole mass giving one the impression of a deeper red than does a single isolated individual.

Examination under magnification shows that the body is somewhat translucent and of a light yellowish tinge, the red color being really due to the blood of the vascular system, since the translucency of the body wall permits the vascular system to show through boldly enough to determine the external appearance. The principal vessels and their connecting branches can easily be traced, and the pulsations of the dorsal vessel may be watched with ease. The white spot in the region of X–XII is due to the presence of developing reproductive elements, and constitutes external evidence of the sexual maturity of the specimen.

LOCOMOTION

The sole mode of progression is a fairly brisk crawling on a supporting surface. A number of experiments were performed with the view of determining the relative efficiency of this mode of locomotion on different surfaces. Specimens were tested with the following substances(both dry and moist)as supporting surfaces: filter rock, sludge, wood (planed surface), ground glass, smooth sheet-iron, and smooth glass. Results showed that the efficiency of the crawling was very much higher on all of the surfaces when they were moist, dry surfaces being an important hindrance to dispersal, and that the degree to which the moist surfaces of the above-named substances favored efficiency of locomotion varied approximately in the order indicated in the list, the maximum occurring on the filter rock and the minimum on smooth glass. The worms crawl with considerable ease over the surfaces of the rock in the sprinkling filter beds, and owing to the irregular shapes of the pieces the interstices form a continuous series of chambers and passages abundantly supplied with sewage and settled solids, through which the worms pass easily. They also have a surprising ability for working their way through the masses of sludge which accumulate on the surfaces of the stone. On a moist ground-glass surface the worms make moderately efficient progress,

but on the moist polished glass progression is slow. The difference in the rate of locomotion on the various supporting surfaces is due to the fact that the setæ, which afford important aid in locomotion, easily or with difficulty find temporary hold on the irregularities of the surface. The crawling consists of an extension of the anterior region and a drawing of the posterior region after it. Although this procedure is the normal and usual one it is, under some circumstances, reversed and the result is a temporary backward movement.

There is no evidence whatever of an ability to progress by swimming. In a series of tests made by placing worms in test tubes full of sewage, they sank, in every case, to the bottom, and were never able to leave it. If placed in water whose depth was less than their length they could often get to the surface by crawling up the side of the dish; but if the water was deeper than their length it was impossible for them to get away from the bottom. They often exhibited random wriggling movements in water, but such motions were ineffectual so far as locomotion was concerned.

RELATION TO LIGHT

Specimens of this species make a decidedly negative response to light. They occur normally below the surface of the filter bed, where practically all light is excluded. No worms were found on the well-lighted surface of the filter bed. In the spring and early summer, when the maximum abundance occurs, the worms often make their appearance in considerable quantity in the effluents of the sprinkling filters, regularly accumulating on the shady side of the secondary settling basins. Filter-bed rock was frequently put into battery jars with worms and placed before a large laboratory window. In such situation the worms invariably crawled away from the light side towards the dark side, and then, if undisturbed, went into the central region of the mass of rock. Sudden exposure to light calls forth a response in the form of active crawling movements which cease when the worms find themselves in a position where the light is distinctly less intense; and exposure to direct sunlight produces an immediate, active, negative response.

RESISTANCE TO DESICCATION

It was noticed that when masses of filter rock which contained worms were brought into the laboratory and exposed to the air, so that evaporation could take place, the gradual drying of the surfaces

at successive depths caused a migration of the worms deeper and deeper into the mass, where moisture was still present. A number of tests were made to determine how long these worms could live when removed from water or wet sludge and transferred to a dry place. The specimens were cleaned and tested singly. There was some variation, but in general the time was limited to 3 to 5 minutes when the experiment was carried on under the conditions which exist at the Testing Laboratory. Beyond this time the worms failed to revive when returned to moist conditions. A mass of the worms, composed of a number of individuals, had a much higher resistance than a single worm.

THIGMOTACTIC RESPONSE

These lumbricillid worms exhibit a considerable degree of positive thigmotaxis. This is shown by the frequency with which numbers of them are seen under natural conditions to progress in aggregations side by side. They are also often found grouped together in masses on the surfaces of the filter-bed rock. When a large number of specimens are transferred to a watch-glass containing tap water they show a distinct tendency to mass themselves around any solid particle or small mass of sludge which may have been transferred with them. This often proved to be of advantage in the putrescibility tests, since the transfers from the different containers could be easily made by picking up the whole mass of one hundred worms at once. The tendency to accumulate in masses seems to be accentuated when the worms are placed under slightly unusual conditions. In case these masses are left undisturbed for a time the worms often ultimately begin to disperse in a rather characteristic manner, moving on the supporting surface in several separate aggregations, the individuals of each lying compactly side by side and all moving in the same direction. Specimens were frequently placed in temporary storage in Syracuse watch-glasses containing a small quantity of water and each one covered by another watch-glass. After these glasses had stood for some time the worms almost invariably accumulated all around the upper rim of the lower watch-glass at the point where the upper glass touched the lower. They apparently preferred a position where they secured the maximum contact with the glass. Specimens kept in Petri dishes commonly accumulated between the perpendicular sides of the upper and lower dish; and those kept in dishes containing wet filter paper usually sought positions between the filter paper and the sides or bottom of the dish.

The normal habit of the worm involves a crawling about over the surface of the rock, to which they cling tenaciously, often making it difficult to pick them off with a needle; and a stream of water must have at least a moderate velocity in order to wash them off. They normally bore into the sludge, and are also often found in the pores of the rock, from which it is quite difficult to extract them.

BEHAVIOR WITH REFERENCE TO DRY AND MOIST SURFACES

A series of experiments was carried on in the laboratory, in diffuse sunlight and at a temperature of about 75 degrees F., in order to determine the behavior of the worms with reference to dry and moist surfaces.

Experiment 1.—A drop-culture slide with concave center and ground-glass top surface was used and the concavity filled with tap water. By means of a large needle a straight continuous trail of water was drawn from the concavity very near to the end of the slide. Worms were then placed at the end of the water trail with the following results:—

1. Slight random movements of the anterior half of the body, which, however, showed the following constant characteristics: (*a*) refusal to move on to the dry surface; (*b*) refusal to move off the end of the slide; (*c*) an apparent recognition of the edge of the water resulting in immediate withdrawal from it; (*d*) exploring movements at the end of the water trail limited to a small area.

2. The worms ultimately found the water trail, and almost invariably followed it uninterruptedly and rapidly to the central cell.

Experiment 2.—This experiment differed from the first only in the fact that the water trail was made very tortuous, and the behavior of the worms was identical with that in experiment 1.

Experiment 3.—In this experiment a long straight water trail was drawn on the surface of a ground-glass slide, without a central cell, and worms were placed at one end of the trail. Aside from occasional stops accompanied by exploring movements the worms followed the trail to the opposite end, retraced the course, and often repeated this performance for a considerable length of time.

RELATION TO TEMPERATURE

The abundance of material made it possible to carry on a long series of experiments, involving a large number of individuals, with the view of determining the temperature limits of life and the effect of different temperatures on the general activities of *Lumbricillus rutilus.*

Vigorous worms just removed from their natural habitat were used in all of the temperature tests, and tap water was used as the medium. Beginning with water at 2 degrees C., tests were made at every degree (in some cases every half degree) up to 45 degrees. Sometimes the process was reversed, the start being at 45 degrees and the temperature being reduced by steps of 1 degree down to 2 degrees C. Unfortunately, facilities were not at hand for making tests with temperatures lower than 2 degrees C., and consequently the minimum life temperature was not determined. All specimens survived 2 degrees C. and were apparently uninjured by it. Results indicated that the maximum temperature is very near 36 degrees C., for while specimens sometimes survived a 36 degrees test an additional half degree proved fatal in a short time, and all temperatures above 38 degrees caused immediate death. The specimens submitted to the higher temperatures were observed under the microscope so that the effect of the heat might be judged as accurately as possible. It is interesting to note that these worms seem adapted to withstand successfully rather low temperatures. A series of tests was carried on by putting a considerable number of worms into flasks containing water to a depth of about 3 cm. and keeping them in the ice box where the temperature was a trifle less than 5 degrees C. The worms lived indefinitely under these conditions. One flask remained in the refrigerator for ten days, and at the end of that time all of the worms were alive, active, and apparently in as good condition as when they were first put in. As to the effect on the activities of the worms, little if any difference could be detected from 10 degrees to 25 degrees C., but below 10 degrees activity decreased, only a very moderate manifestation being evident at 2 degrees. It was noted that this decrease in activity was not uniform, being more marked from 5 to 2 degrees than from 10 to 5 degrees. Above 25 degrees activity increased as the temperature was raised.

From these data it would appear that so far as temperature is concerned the worms could exist in the sprinkling filters the year round, since the latter are in constant operation and never freeze. Evidently some factor other than temperature is effective in the reduction of the numbers of the worms in late summer and autumn.

RELATION TO OXYGEN

The Normal Supply of Oxygen.—As has been stated before, a sprinkling filter is a device designed primarily to effect the oxidation of the sewage which is delivered to it, and, as a consequence, the organisms which live in these filters are well supplied with oxygen,

which comes to them in two ways: (1) direct from the air by contact, and (2) from the sewage, which contains dissolved oxygen when it enters the filter bed.

In all of the sprinkling filters except No. 3 the stones composing the filter bed are of a size which produces a series of continuous and rather spacious interstices. These may be reduced to some extent by the settling material from the sewage but as they never become completely filled they constitute a series of air spaces and thus form a source of oxygen supply for the organisms inhabiting them. That these lumbricillid worms take oxygen directly from the air is shown by the fact that specimens have been kept for several days in vessels containing moist filter paper which served to prevent the undue drying of the worms. This was also demonstrated when at one time an accident to the pumping machinery eliminated for over three days the possibility of oxygen from sewage reaching the worms, the only liquid present in the upper zone being that held by the sludge.

The sewage, which constitutes the influent of the sprinkling filters, coming as it does from the settling and septic tanks, has a very low dissolved oxygen content, often showing a total absence of dissolved oxygen, particularly during the hot season. However, this influent passes through a nozzle which breaks the stream up into a spray, throwing it out into the air, and this, in falling, is distributed over the whole of the top surface of the filter bed and between its individual stones. The result of this process is that the liquid becomes oxygenated to a considerable degree. The spraying also brings about the loss of most of the carbon dioxide. Consequently, regardless of its source, the sewage which flows over the worms has a considerable dissolved oxygen content. The effectiveness of the sprinkling filter as an oxygenating device is shown by the fact that in filter No. 4 on certain days in September and October, 1912, when the influent (at the entrance of the nozzle) showed a total absence of dissolved oxygen, the effluent contained from 11.2 to 14.7 p.p.m. That this oxygen can be utilized by the worms is shown by the fact that when placed in tap water they lived for days, and even weeks, under conditions which prevented their getting oxygen from any other source.

Resistance to Decreased Oxygen.—It would seem that organisms as active as these worms would require a considerable amount of free oxygen, and that the sprinkling filter environment is such as to afford a generous supply. A number of extended experiments were made with the view of determining the effect of a decreased supply of oxygen. The methods employed in these experiments are as follows:

A series of samples of tap water whose dissolved oxygen content ranged from 1.2 p.p.m. to 9.2 p.p.m. was used as a medium. The highest dissolved oxygen sample (9.2 p.p.m.) was obtained by agitating the water in air. Tests were also made in which the medium was the sprinkling filter effluent, its dissolved oxygen content varying from 10 to 13 p.p.m. Samples with the lower dissolved oxygen content were procured either by mixing boiled tap water with different quantities of ordinary tap water or by boiling a considerable quantity of tap water and allowing it to stand in an open vessel, samples being taken at successive intervals as the water gradually absorbed oxygen from the air. Sampling bottles of 128 cc. corrected capacity were used, and care was taken that each was so stoppered that no air bubbles were included. Two samples of each of the different grades of water were taken, one being used for the worms and the other for the determination of the dissolved oxygen content. Ten vigorous worms, fresh from the filters, were quickly transferred to one of the bottles and the time noted. The worms were thoroughly cleaned before they were put into the bottles. This procedure was followed for each of the series of samples taken. The bottles were all kept under conditions which simulated those existing in the sprinkling filter and were observed frequently.

It might appear that a source of error existed because no account was taken of the carbon dioxide and the nitrogen in the samples. When water is boiled it loses most of the dissolved oxygen, nitrogen, and carbon dioxide, and when oxygen was added to the samples by exposure to the air or by the addition of ordinary tap water, certain quantities of nitrogen and carbon dioxide were also added. However, the writer believes that this source of error did not interfere with the essential results of the experiments. The carbon dioxide in the sprinkling filter is an extremely variable quantity, since much of the gas must be lost when it is sprayed out into the air, and consequently the liquid coming to the worms probably contains but small quantities of carbon dioxide—a condition comparable to that in the sampling bottles of the experiments. Only a very limited amount of nitrogen (dissolved) is present in the sprinkling filter influent. When the tap water, which contained a certain quantity of nitrogen, was boiled the major part of the nitrogen was lost. In those samples made up by mixing the boiled and unboiled tap water some nitrogen was added with the latter, while in the samples made by exposure of the boiled water to the air nitrogen was taken up from the air very slowly, so that in all cases the samples closely approximated the conditions in the sprinkling filter. Of the three gases involved the oxygen was

the only one which was varied widely in the experiments. Other workers have found that it is very difficult, in fact almost impossible, by methods known at present to vary absolutely a single gas in this kind of experimentation, and thus a small source of error indubitably exists. It is thought, however, that in this case it may be practically negligible, since the sole aim of the experiments was to determine the general effect of a decreased supply of oxygen on the worms.

The dissolved oxygen content of each sample was determined by using Winkler's method as outlined in "Standard Methods of Water Analysis", 1912. Briefly stated, a solution of manganous sulphate was added to the sample and followed by an alkaline solution of potassium iodide. The precipitate of manganous hydrate was allowed to settle. Sulphuric acid was then added, and the free iodine in the solution was titrated with a standardized solution of sodium thiosulphate. The equivalent of free iodine was calculated to oxygen and the results expressed in parts per million.

The following tabular exhibit of the results of one of the experiments will serve as a representative of other, similar ones made in this connection.

No.	Corrected capacity of bottle, in cc.	Sodium thiosulphate, in cc.	Oxygen, in p. p. m.	Number of worms	Time lived, in hours
1	128	0.8	1.25	10	21
2	128	1.1	1.7	10	27
3	128	1.7	2.6	10	42
4	128	1.9	2.9	10	47
5	128	3.5	5.4	10	65
6	128	5.7	8.9	10	75
7	128	5.99	9.2	10	142

The data of the other experiments carried on in this connection varied in detail to some extent from the preceding, but the general showing was the same, namely, that it is indispensable to the well-being of these worms that they should have oxygen in considerable quantities. To judge fairly concerning the deleterious effect of reducing this normal requirement, as in these tests, it is necessary to keep in mind the fact that in each of the samples the water gradually becomes poorer in oxygen since it was constantly being used in the

respiratory activity of the worms and, very probably, to a small extent, in the oxidation of their excretory products. Although the data seem to show that the worms are sensitive to a lowering of the dissolved oxygen content and that it is inimical to them, it does not necessarily follow that the death of the worms was due to a complete exhaustion of oxygen in the sample, since it was shown that it sometimes occurred when considerable oxygen remained unconsumed. For example, the water used in No. 6 of the above table, containing at first 8.9 p.p.m. of dissolved oxygen, when tested at the end of the experiment still contained 4.2 p.p.m.—a quantity which as the initial content in one of the other experiments sufficed the worms for 98 hours. It was not possible in these experiments to remove the excretory products from the water and thereby eliminate the possibility of this accumulating waste influencing the vital activities of the worms; but in an experiment made in another connection, a similar quantity of worms were kept in 45 cc. of water in an open flask and at the end of ten days all were alive and apparently as active as at the beginning. Since in this last case the quantity of water was so much smaller and the length of time so much greater than in the above experiment it seems fairly certain that accumulating wastes did not contribute in an important degree to the death of the worms. Furthermore, the normal habitat is one in which organic wastes are at a maximum.

RELATION TO SEWAGE

Relation to Crude Sewage.—In another connection the fact was brought out that no worms were found in the septic and settling tanks, which receive the crude sewage. This was attributed chiefly to the lack of dissolved oxygen. Tests were made by placing vigorous worms in bottles of crude sewage so corked that no air was included or could gain access. Other tests were made by placing worms in a flask which was about half filled with crude sewage, thus leaving a large air space above the surface. In tests by the first method the worms lived but 10 to 12 hours. Under the conditions of the second test one lot lived 72 hours, which may be accounted for by the absorption of air by the sewage from the air space above, a limited oxygen supply being thus furnished for the worms. However since the sewage itself contained putrescible matter which also drew heavily on the oxygen supply, the continued low oxygen content had a fatal effect.

Behavior in the Presence of Sludge.—The following experiments were performed in this connection:—*Experiment 1.* A ground-glass

slide was used and a water trail was drawn lengthwise of it. A mass of moist sludge from the filter stones was placed at one end and the worms were placed at the other end. They followed the water trail to the sludge, crawled around it and through it, and became quiet. *Experiment 2.* A circular cover-glass was supported on bits of filter paper, water was run under it and a water trail was drawn from it. Ten worms were placed at the end of the trail. The worms followed the trail to the cover-glass but would not pass under it. *Experiment 3.* The procedure was the same as in Experiment 2 except that black paper was placed on the cover-glass the space under it being somewhat darkened. The behavior of the worms was the same as in No. 2. *Experiment 4.* The procedure was the same as in No. 2 except that a mass of sludge from the sprinkling filter was placed under the cover-glass. In every case tried the worms passed under the cover-glass in a short time, and after surrounding and penetrating the sludge became quiet.

It is not possible to explain, from the data, the behavior of the worms with reference to the cover-glass in experiments 2 and 3. In neither case did the worms pass under it, and in spite of the fact that these forms are negatively phototactic, the area under the darkened cover-glass in experiment 3 was avoided. There was evidently some unknown factor present which was sufficiently active to overcome the negative phototactic tendency of the worms and to prevent their migration into more favorable light conditions. The experiments show, however, a distinct recognition by the worms of the presence of sludge and a positive reaction to it. Furthermore, it is evident that this positive reaction is sufficiently strong to overcome the opposing influence which prevented the worms from passing under the cover-glass in experiments 2 and 3. The experiments showed also that the positive reaction to the sludge was not due to negative phototaxis since the worms did not pass under the cover-glass in experiment 3.

Relation to the Sludge in the Sprinkling Filters.—That these worms have a mechanical effect on the settling suspended matter which accumulates in the filters is readily seen. They are constantly burrowing through the masses of sludge, and since they occur in such large numbers they must play a prominent part in loosening up the sludge and working it over, thus facilitating the oxidation of the unstable organic matter.

It has been observed at the Testing Station that during the winter the sprinkling filters become clogged to a considerable extent; that is, in the Station parlance, they build their load by accumulating a large quantity of sludge. This sludge is held in the filter until the tempera-

ture begins to rise in early spring, and then the filter begins to "unload" and the effluent becomes laden with large quantities of heavy earthy suspended matter and the sludge in the sprinkling filter becomes rapidly reduced. The significant thing in this connection is the fact that this unloading period is coincident with the maximum abundance of the worms, which decrease somewhat in number soon after the greater part of the unloading has occurred. Whether or not the worms are responsible for the unloading remains to be proven, but the circumstantial evidence indicates that they are at least partly responsible for it. Cognizance must, however, be taken of the fact that other organisms also are abundant in the sprinkling filter at this time, and it is possible that the unloading is the result of the combined mechanical action of a number of associated organisms.

Relation to Putrescibility.—Before going into the discussion of the experiments which were made in this connection it is necessary to make clear the meaning of certain important terms which are in constant use in sewage investigations.

In order to explain what is meant by the term *putrescibility* and to indicate its precise application in sewage disposal work it is necessary to explain in considerable detail certain chemical and physical conditions which exist in ordinary sewage. Phelps ('09, p. 75) gives a very clear account of the application of this term in the following rather lengthy quotation:—

"Putrescibility, as applied to organic matter in general, implies the ability of that matter to undergo offensive putrefactive decomposition. . . . . . Such decomposition is always anaerobic and it is usually accompanied by the evolution of offensive odors. These two phenomena have, therefore, formed the basis of most putrescibility tests. Some criteria of putrefaction which have been employed are: (1) Development of offensive odors; (2) formation of black sediment; (3) reduction in the amount of dissolved oxygen; (4) loss of all dissolved oxygen; (5) loss of all available oxygen, including that of nitrates and nitrites; and (6) increase in the oxygen-consumed figure. Some of these tests are based on partial reduction of the available oxygen in the effluent; others depend on the complete reduction of the available oxygen and subsequent anaerobic fermentation. The tests most commonly employed belong to the latter group, depending on the production of odor or of hydrogen sulphide, blackening of the liquid, or reduction of organic dyes. The test which depends on an increase in the oxygen-consumed figure during incubation is also in that class, because anaerobic fermentation alone renders organic matter more readily oxidizable.

"These two types of test illustrate two distinct points of view which should be clearly differentiated. An effluent may be regarded as being composed of a given mass of organic matter dissolved or suspended in a definite amount of water. The water contains also a definite amount of available oxygen in the form of free dissolved oxygen, nitrites, nitrates, and possibly of other compounds. All the organic matter is oxidizable to some extent, and to that extent it serves as bacterial food. The greater the amount of organic matter and the greater its oxidizability, the greater is the absorption of oxygen from the medium. Consequently a reduction of available oxygen in the effluent during incubation is a measure both of the amount of organic matter present and of its capability of oxidation. As a small amount of readily oxidizable matter has the same effect on the result as a larger amount of more stable matter, a test of this kind indicates whether or not the organic matter consumes oxygen; but it does not show whether or not the supply of available oxygen is sufficient to prevent the establishment of anaerobic conditions. This important question of the balance between the oxygen demanded by the organic matter and the oxygen available in the liquid is taken into consideration by tests of the second kind mentioned, namely, those dependent on the establishment of anaerobic conditions. Such tests do not involve estimation of the amount and the kind of organic matter; indeed, organic matter which does not absorb any oxygen from the liquid under the conditions of an incubation test must be very highly oxidized; and, furthermore, most organic matter derived from sewage is putrescible in itself—that is, if it is stored by itself in the absence of oxygen, it undergoes putrefactive changes. The question at issue is not, however, whether the organic matter itself will putrefy, but whether the effluent as a whole will become so reduced in oxygen that putrefaction will become possible. In other words, it is simply a question of a balance between the available oxygen of the effluent and the oxygen which the organic matter will require during the incubation period. It would seem that the problem might readily be solved by determining this balance, but, unfortunately, it is not a simple matter, because the action involved is bacterial. Many attempts have been made to determine the oxygen balance analytically, but such tests answer only with very good and very bad effluents, for which an inspection of the sample would serve just as well. When there is doubt about the character of the effluent—the condition for which such information is of most value—all such analytical procedures have heretofore failed. It is evidently impossible to imitate with any degree of precision the bacterial activities that

are involved. There remains, then, but one satisfactory expedient: To let the reaction proceed by itself and to note the result. But here also there are difficulties, because bacterial reactions of this sort are necessarily slow in reaching equilibrium, and the time required by a nicely balanced effluent is greater than can be allowed in routine work. Some arbitrary period of time, therefore, is usually adopted, and it is in respect to this factor that the confusion arises. If stability is to be considered a definite qualitative characteristic of an effluent, that characteristic should be determined by a test sufficiently prolonged to insure equilibrium, but such procedure is not feasible for obvious practical reasons, and it is not desirable, because it is not enough simply to know that the available oxygen is sufficient or insufficient to satisfy the demands of the bacteria that are working on the organic matter. If the available oxygen is sufficient, there is perfect stability—a definite condition; if it is insufficient, there is still stability in the quantitative sense—a relative stability determined by the relation of the available oxygen to the total amount of oxygen required by the organic matter for perfect stability. In practice the latter condition is the one usually encountered."

Owing to the varied meanings which are attached to the word putrescibility, Phelps ('09, p. 77) has recommended the word stability to designate "that desirable quality which is the usual object of sewage purification—the transformation of the organic matter to such a form that it is incapable of undergoing offensive putrefaction." He argues that the term *stability* implies a positive characteristic which is acquired during the purification process, while the term putrescibility refers to a negative characteristic. Stability describes that condition in which the available oxygen exceeds the required oxygen. The term putrescibility has, however, been retained in this paper owing to the fact that it is still largely in use in the literature which deals with sewage investigation.

From the economic point of view questions bearing directly upon the putrescibility of sewage are of the greatest importance. The ultimate aim of all sewage disposal operations is to render the putrescible matter as stable as possible, and any factors which facilitate or hinder this process are of considerable practical importance. Since, then, these lumbricillid worms occur in such great abundance in connection with devices which are operated to overcome the putrescibility of sewage their possible favorable or unfavorable relation to this process is a pertinent subject of inquiry.

The purpose of the following experiments was to discover, if possible, just what effect these organisms have on putrescibility. Tests

were made on the following grades of sewage: (1) raw sewage, (2) septic-tank effluent, (3) settling-tank effluent, and (4) sprinkling-filter effluent. The suspended matter in sewage is of two kinds, namely, the settling and the non-settling suspended matter. The former is of such a nature that it can be removed by filtration through ordinary filter paper, or will be deposited when sewage is stored; but the latter must be removed by chemical precipitation, by biologic treatment, or by the use of special filtering devices. The non-settling suspended matter is colloidal in nature and is known as the pseudo-colloidal content of sewage. Each of the four above-mentioned effluents were tested in three ways: (1) by using the raw material, (2) by using the sewage after its passage through ordinary filter-paper, which removed the settling suspended matter, and (3) by using the material from which the settling suspended matter had been removed by filtration and the pseudo-colloidal matter had been removed by filtering the liquid through a Gooch crucible connected with a filter pump. Since investigation has shown (Lederer, '12b) "that the finely divided slowly settling suspended matter and the pseudo-colloidal matter not capable of settling make up the greater part of the putrescibility," the tests were made in a way to permit a study of the effect of the worms on the liquid when one or both of the above-mentioned substances are present. The sampling bottles of the Sewage Testing Station were used in the tests. These bottles have a capacity of 128 cc. All of the glassware, such as pipettes, sampling bottles, etc., was sterilized before using. The bottles were filled with the various grades of sewage and then worms were transferred to each. Vigorous worms fresh from the sprinkling filter were used in every case. Before they were put into the test bottle they were carefully cleaned by transferring them from one to another of a series of vessels containing pure water, in order to prevent extraneous material from entering with them. They were then counted out in lots of 100, and after removing all excess water each lot was weighed on a fine analytical balance, and those lots which weighed approximately the same were selected for the tests. Each lot was placed in a separate bottle which was corked in such a way that no air bubbles were enclosed. For each individual test a check experiment was carried on, similar in all respects except that no worms were used. Thus a single series involved twenty-four tests.

Determinations of putrescibility involve the use of delicate indicators which aid in the accurate detection of the beginning of an-

aerobic conditions. In these experiments Spitta and Weldert's Methylene Blue Putrescibility Test was used. This test depends upon the formation of a colorless leucobase as the oxygen in the sample becomes exhausted. The technique is simple. One cc. of 0.1 per cent. aqueous solution of methylene blue is added to the sample, which is then kept in an incubator either at 20 degrees C. or at 37 degrees C. and observed frequently. The blue color of the sample remains practically unchanged until the available oxygen contained in it has been consumed and putrefactive conditions have been established. At this time the dye is reduced and the color disappears. The time for the decoloration (reduction time) therefore indicates quite closely the time at which the available oxygen is consumed. Phelps ('09, p. 77) added further value to the methylene blue test by putting it on a quantitative working basis so that the putrescibility of a given sample can be expressed in terms of relative stability. This makes it possible to indicate the proportion of the oxygen present as compared with the total amount required to oxidize a given sample.

This test lends itself to this kind of experimentation, since beside making it an easy matter to determine the reduction time the presence of the methylene blue in the sample has little or no deleterious effect on the worms. At the time that the worms were transferred to the bottle 1 cc. of a 0.1 per cent. aqueous solution of methylene blue was added to each bottle and the time carefully noted. These test bottles together with the checks were placed in a constant-temperature incubator at 20 degrees C., and careful watch was kept and the reduction time of each noted.

The worms in the sampling bottles were frequently observed in order to determine whether or not any of them died while under these conditions, since it is evident that the death of any of them would constitute a source of error by increasing quantitatively the amount of putrescible matter in the sample. Fortunately the mortality was very low, so low that the writer feels confident that it did not vitiate the results of the experiments. The following table indicates the results of one of the series.

EFFECT OF WORMS ON PUTRESCIBILITY

Sample	Putrescibility, in hours	Relative stability	Loss in relative stability	Percentage relation of actual loss to possible loss
Crude sewage				
Check	12	11		
Test (100 worms)	11	10	1	9.09
Crude sewage, filtered; pseudo-colloids present				
Check	32	26		
Test (100 worms)	24	21	5	19.2
Crude sewage, filtered; pseudo-colloids removed				
Check	66	47		
Test (100 worms)	29	24	23	48.9
Septic-tank effluent				
Check	3	3		
Test (100 worms)	2	2	1	33.3
Septic-tank effluent, filtered; pseudo-colloids present				
Check	17	15		
Test (100 worms)	14	12	3	20.0
Septic-tank effluent, filtered; pseudo-colloids removed				
Check	50	37		
Test (100 worms)	29	24	13	35.1
Settling-tank effluent				
Check	14	12		
Test (100 worms)	12	11	1	8.3
Settling-tank effluent, filtered; pseudo-colloids present				
Check	35	28		
Test (100 worms)	31	25	3	10.7
Settling-tank effluent, filtered; pseudo-colloids removed				
Check	50	37		
Test (100 worms)	27	22	15	32.4

EFFECT OF WORMS ON PUTRESCIBILITY—*Continued*

Sample	Putrescibility, in hours	Relative stability	Loss in relative stability	Percentage relation of actual loss to possible loss
Sprinkling-filter effluent				
Check	480	99		
Test (100 worms)	37	30	69	69.6
Sprinkling-filter effluent, filtered; pseudo-colloids present				
Check	480	99		
Test (100 worms)	43	34	65	65.6
Sprinkling-filter effluent, filtered; pseudo-colloids removed				
Check	480	99		
Test (100 worms)	43	34	65	65.6

Dates of collection and bottling, October 10-19, 1912.
Incubation temperature, 20 degrees C.
Relative stability numbers calculated according to Phelps.

An examination of the results of all of the experiments made in this connection, of which the above series is a part, shows that the most conspicuous result is the marked increase of putrescibility in the test samples containing the worms as compared with the check samples, which contained no worms. This was a constant feature of all of the experiments. In no case was there an opposite result. The presence of the worms increased the putrescibility under all conditions as regards the presence or absence of the various kinds of suspended matter in the sewage. The reduction time increases with the removal of suspended matter and the difference between the reduction time of the test and that of the check experiments tends to become greater as suspended matter is removed. Increased putrescibility means loss in stability and the loss in relative stability apparently increases with the removal of suspended matter.

The explanation of the manner in which this increase in putrescibility is produced by the worms has not been determined. The exhaustion of the oxygen may be accomplished in two ways, (1) by the respiratory activity of the worms, and (2) by means of the organic matter contributed in the form of excreta. From a practical standpoint it does not matter by what means the worms reduce the oxygen. The important fact is that the *oxygen is being used up*. As has been

stated before, the sprinkling filter is a device for oxygenating the sewage which is delivered to it, thus rendering it more stable, hence the presence of anything in the filter which draws upon the oxygen is thus decreasing the efficiency of the filter. The evidence seems to be conclusive that the presence of these worms in the sprinkling filter increases the putrescibility of the sewage by using up a part of the available oxygen, and since they occur in great numbers in the sprinkling filters for the greater part of the year there is good reason to believe that in so far as their relation to the available oxygen is concerned the effect of their presence in the sprinkling filter is a detrimental one. If, on the other hand, it be true that at all times of the year there is a distinct vertical distribution of the worms in the sprinkling-filter, in which the larger number is confined to the upper two or three feet, the detrimental effects of their presence may be overcome to some extent, since the interstices of the filter stones constitute air spaces by means of which the loss of oxygen in the upper zone due to the activity of the worms may be mitigated to some extent by the passage of the sewage through the air spaces of the lower parts of the filter bed. Nevertheless, the fact remains that the worms increase putrescibility, and their presence in sprinkling filters is apparently undesirable. It is possible that when the problem of the relation of these worms to sewage has been completely worked out it may be found that the advantageous relations may more than offset the harmful ones, but until further investigation is made this point must remain unsettled.

Summary

1. The following new species of *Enchytræidæ,* distributed among four genera, have been added to the list of American forms.

Name	Type locality
Henlea moderata	Urbana, Ill.
Henlea urbanensis	Urbana, Ill.
Lumbricillus rutilus	Chicago, Ill.
Fridericia douglasensis	Douglas Lake, Mich.
Fridericia oconeensis	Oconee, Ill.
Fridericia sima	Urbana, Ill.
Enchytræus gillettensis	Gillette Grove, Iowa

2. Chylus cells were found only in *Fridericia.* The characters of these cells are distinct for each species examined, and show evidence of taxonomic value.

3. Studies on the penial bulb in fourteen species distributed among five genera have shown the writer that in this material its structure is uniform in the specimens of a given species, and that it seems to furnish characters of taxonomic importance. Eisen's classification of the subfamilies and genera based on the characters of this organ is, however, faulty. In *Marionina* provision must be made in the definition for the occasional presence of an accessory gland in connection with the penial bulb. The stability of the subfamily *Enchytræinæ* is very uncertain, since it contains only one genus, *Enchytræus*, which is now known to contain a few species in which the penial bulb is of the lumbricillid type, species which have the enchytraeid type of penial bulb, and species which have transitional forms of the bulb connecting the regular types. Alterations must be made in Eisen's characterization of the bulb in the genus *Fridericia* to provide for wider variation in the number of sets of cells in this organ.

4. Stephenson has recently described species which have characters transitional between *Lumbricillus* and *Enchytræus*. Additional evidence of the close relation of these two genera is now offered, since it is shown that the penial bulb of the latter shows distinct transitions between the enchytræid type and the lumbricillid type. These two genera were formerly regarded as standing far apart.

5. The remainder of the summary refers to a single species, *Lumbricillus rutilus* n. sp. This enchytræid occurs in abundance in the sprinkling filters of the Chicago Sewage Testing Station during the warm months of the year. Its distribution in the various tanks and filters depends chiefly upon the dissolved oxygen content, the hydrogen sulphide content, and the "freshness" of the influent. It was found associated with numbers of other species of animals, of which the following are the most common: *Prorhynchus* sp., *Nematoda, Pristina* sp., *Nais* sp., *Helodrilus subrubicundus, Collembola* (*Isotoma* sp.), larvæ and pupæ of *Psychoda albimaculata* and *Chironomidæ,* and water-mites.

Its sole mode of progression is by crawling, rough moist surfaces favoring dispersion and dry ones constituting an important hindrance to it. There is no evidence of an ability to swim.

These worms are sensitive to light and show a decidedly negative response to it.

Exposure to dry conditions results fatally within a short time—usually less than five minutes.

These worms are positively thigmotactic, showing a distinct tendency to accumulate in masses and to orient themselves in such a way

that a maximum of contact with the sludge and the filter-bed rock is secured.

The maximum life-limit temperature for these organisms is very near 36 degrees Centigrade. In temperatures ranging from 25 to 10 degrees no difference in the activities of the worms was noticed, but from 10 to 2 degrees activity was reduced. They can live in a temperature of 5 degrees for days and even weeks.

These worms require an abundant supply of oxygen. Continued low dissolved-oxygen content in the medium has a deleterious effect, and the great abundance of these forms in the sprinkling filters is due in part to the high dissolved-oxygen content of the sewage which comes in contact with them. They can not thrive in crude sewage.

The worms show a distinct recognition of the presence of sludge, and react positively to it. In the sprinkling filters they loosen up the accumulating sludge and work it over, thus facilitating the oxidation of the unstable organic matter. Circumstantial evidence indicates that it is at least partly through the agency of these worms that the "unloading" of the sprinkling filter occurs in spring.

Experiments have shown that these worms increase the putrescibility of the sewage in which they occur. This is a fact of economic importance. They thus interfere with the efficiency of the sprinkling filter and aid in rendering the sewage unstable, faciliating anaerobic decomposition. In this particular respect they are undesirable organisms in sewage disposal plants.

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EXPLANATION OF PLATES*

Abbreviations

bl. s., blood sinus.
ch'l. c'l., chylus cell.
cil., cilia.
circ. mu., circular muscle layer.
cl. c'l., clitellar cells.
cut., cuticula.
d. bl. v., dorsal blood-vessel.
ec. op., ectal opening.
ec. sp'r. gl., ectal spermathecal gland.
en. ep. c'l., ental epithelial cell.
en. op., ental opening.
en. sur., ental surface.
hyp., hypodermis.
in. b. c'l., inner bulb cells.
in. c'l. c'n., intracellular canal.
l. cyt., lining layer of cytoplasm.
lum. dig. tr., lumen of digestive tract.
lum. div., lumen of diverticulum.
m., musculature.
n., nucleus.
or. tu. div., origin of tubules of diverticulum.
p., peritoneum.
pen. b. i., penial bulb invagination.
pen. lum., penial lumen.
pen. po., penial pore.
per. gl. c'l., peripheral gland cells.
r. m., retractor muscle.
sp. d., sperm duct.
sp'r. d., spermathecal duct.
tu. div., tubules of diverticulum.

Plate VIII

Henlea moderata

Fig. 1. Outline of brain, dorsal view.
Fig. 2. Outline of nephridium.
Fig. 3. Seta bundle.
Fig. 4. Spermiducal funnel.
Fig. 5. Lymphocyte.
Fig. 6. Outline of anterior end, lateral view.
Fig. 7. Spermatheca.
Fig. 8. Part of transverse section of digestive tract in region of taste organs.
Fig. 9. Seta.
Fig. 10. Transverse section of intestine in posterior part of VIII, through origin of tubules of intestinal diverticulum.
Fig. 11. Transverse section through intestinal diverticulum.
Fig. 12. Penial bulb in a transverse section of the worm.

[*Henlea urbanensis*]
[For explanation see under Plate XII]

Lumbricillus rutilus

Fig. 13. Outline of anterior end, showing details of blood vascular system.

Plate IX

Lumbricillus rutilus—cont.

Fig. 14. Spermiducal funnel, surface view.
Fig. 15. Outline of nephridium.
Fig. 16. Outline of spermatheca.
Fig. 17. Sectional view of spermiducal funnel.
Fig. 18. Transverse section of ventral gland in XIII.
Fig. 19. Transverse section of ventral gland in XIV.
Fig. 20. Outline of ventral glands in XIII and XIV, dorsal view.
Fig. 21. Seta bundle.
Fig. 22. Outline of brain, dorsal view.
Fig. 23. Longitudinal section of spermatheca.
Fig. 24. Penial bulb in a transverse section of the worm.

*Illustrations by the author.

Fridericia douglasensis

FIG. 25. Diagram of the chief blood vessels in anterior region.
FIG. 26. Superficial section of the clitellar cells.

PLATE X

Fridericia douglasensis—cont.

FIG. 27. Outline of nephridium.
FIG. 28. Spermatheca.
FIG. 29. Spermiducal funnel.
FIG. 30. Seta.
FIG. 31. Outline of brain, dorsal view.
FIG. 32. Penial bulb in a transverse section of the worm.
FIG. 33. Part of longitudinal section of intestine in chylus cell region.
FIG. 34. Peptonephridium.

Fridericia oconeensis

FIG. 35. Outline of brain, dorsal view.
FIG. 36. Outline of nephridium.
FIG. 37. Spermatheca.

PLATE XI

Fridericia oconeensis—cont.

FIG. 38. Part of transverse section through intestine in chylus cell region.
FIG. 39. Peptonephridium.
FIG. 40. Spermiducal funnel.
FIG. 41. Transverse section through intestine in chylus cell region.
FIG. 42. Penial bulb in a transverse section of the worm.

Fridericia sima

FIG. 43. Peptonephridium.
FIG. 44. Outline of nephridium.
FIG. 45. Outline of nephridium of another form.
FIG. 46. Part of transverse section through intestine in chylus cell region.
FIG. 47. Outline of anterior end.
FIG. 48. Outline of brain, dorsal view.
FIG. 49. Outline of longitudinal section through spermiducal funnel.

PLATE XII

Fridericia sima—cont.

FIG. 50. Spermatheca.
FIG. 51. Penial bulb in a transverse section of the worm.

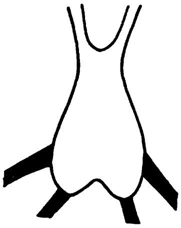
Enchytræus gillettensis

FIG. 52. Outline of brain, dorsal view.
FIG. 53. Outline of longitudinal section through spermatheca.
FIG. 54. Outline of nephridium.
FIG. 55. Outline of spermiducal funnel.
FIG. 56. Penial bulb in a transverse section of the worm.

Henlea urbanensis

FIG. 57. Spermatheca.
FIG. 58. Penial bulb in a transverse section of the worm.
FIG. 59. Intestinal diverticulum in a transverse section of the worm.

PLATE VIII



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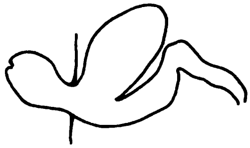

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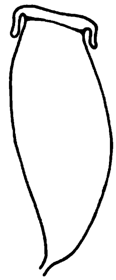

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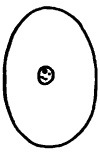

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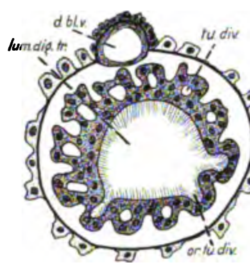

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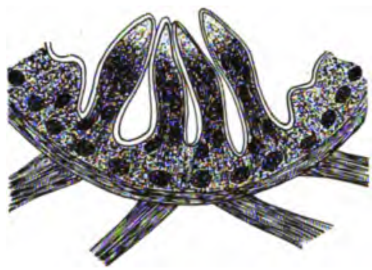

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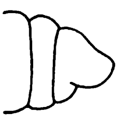

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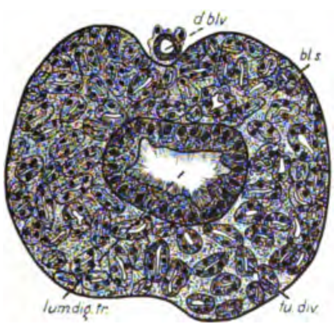

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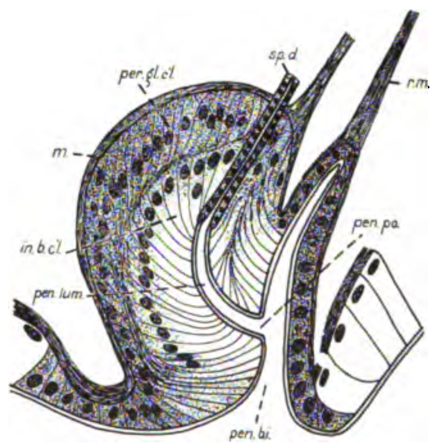

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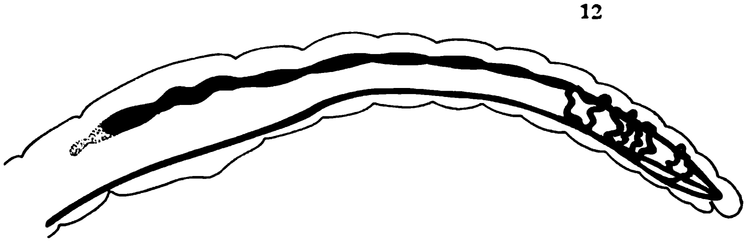

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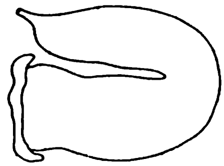
Plate IX



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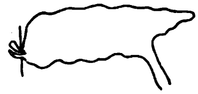

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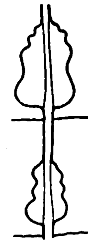

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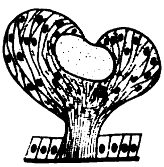

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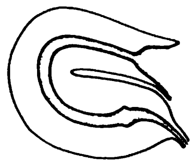

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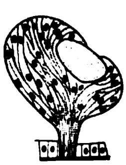

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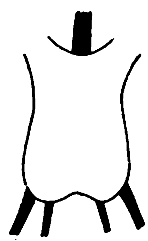

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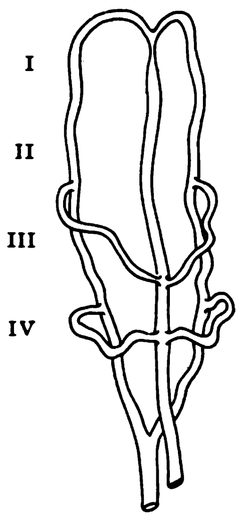

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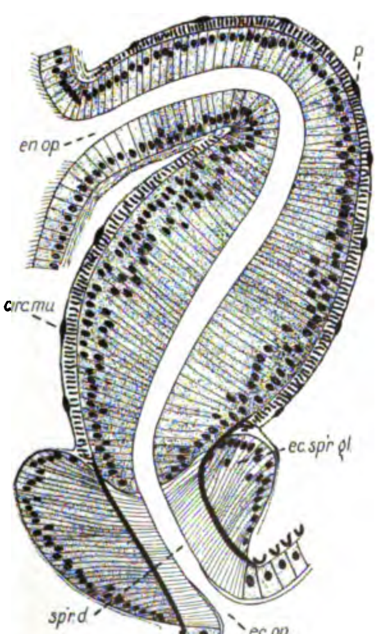

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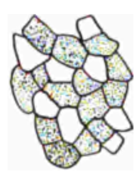

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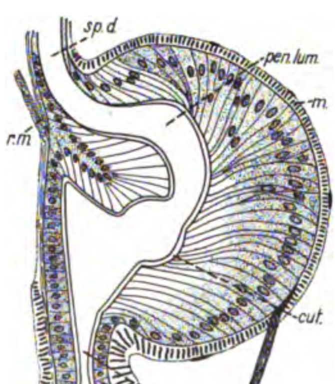

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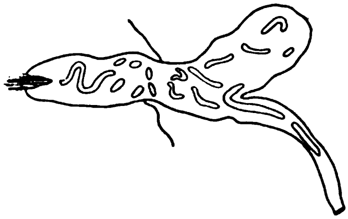
PLATE X



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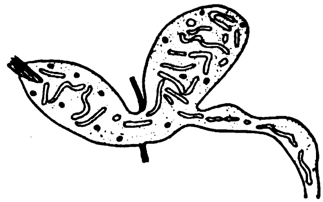

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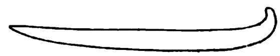

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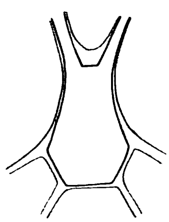

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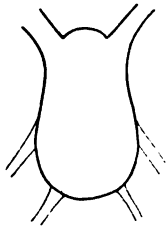

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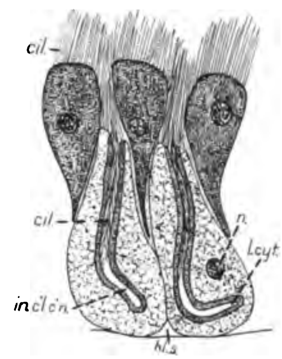

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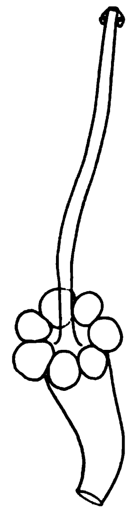

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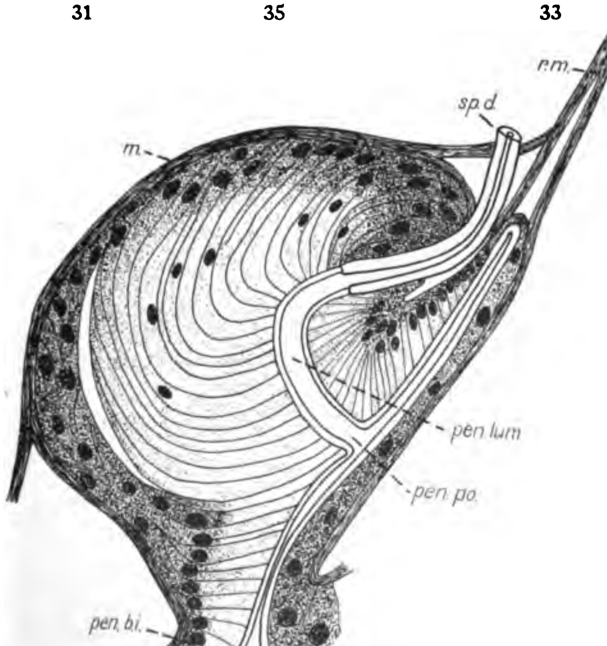

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